5.0 IN-RIVER DISTRIBUTION OF ~~INDICATOR CHEMICALS~~CONTAMINATION

This section presents information on ~~T~~the distribution of ~~ICs~~ contamination in the river environment ~~in sediment, in-river sediment traps, surface water, TZW and groundwater seeps, and biota is summarized in this section.~~[1] based on data collected through July 19, 2010 and focuses on the in-river contaminant distribution in- and immediately adjacent to the Study Area, as well as up- and down-river of the Study Area.~~,~~[2] ~~-~~ Section 5.1 presents the criteria for selection of contaminants for discussion and use in the RI; Section 5.2 discusses the in-river distribution of contaminants in bedded sediments; Section 5.3 discusses mobile sediment (as measured in sediment traps or borrow pits~~)~~; Section 5.4 discusses the in-river distribution of contaminants in surface water; Section 5.5 discusses the distribution of contaminants in transition zone water and groundwater seeps; and Section 5.6 discusses the distribution of contaminants in biota.

The discussions in the following subsections focus on distribution of contamination as orders of magnitude of detected values (e.g., <1, 1-10, 10-100, 100-1,000, etc.). Depending on the medium examined, the discussion of contaminant distribution is supported by a variety of tabular and graphical materials: 1) maps showing the extent of each contaminants distribution, 2) summary statistics tables, 3) scatter-plot graphs depicting chemical concentrations by river mile, and 4) histogram and box-whisker plots for comparing values and distributions. The summary statistics tables present frequency of detection, minimum, maximum, mean, median, and 95th percentile, and the station locations of the maximum values. Summary statistics are calculated using only detected values only as well as combined detect and nondetect values. These statistics have been compiled separately for the RI Study Area reach (RM 1.9–11.8), exclusive of the Multnomah Channel), the downtown reach (RM 11.8-15.3), the up-river reach (RM 15.3-26) and the down-river reach (RM 0-1.9) [refer to Map 5.0-1]. Summary statistics for sediments include both point samples and beach composite samples to provide a general understanding of contaminant concentration distributions.

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Where specific sample results are cited in the text (i.e., the concentration of a sample, median and 95th percentile values) qualifiers associated with that result are also cited, with one exception. The qualifier "T" is not cited as it generally indicates that the result was mathematically derived through summing multiple results (e.g., total PCB congeners equal the sum of the PCB congener results). The "T" qualifier may also indicate that a result is an average of multiple results for a single analyte (e.g., field replicates) or that a result was selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods). The following qualifiers are cited with the results:

[1] ~~The discussion of chemical nature and extent may include use of facility names and landmarks (e.g., bridges) for location references; mention of such names does not necessarily indicate a source or origin.~~

[2] ~~Section 5 text, maps, figures, and tables are based on the data lockdown date~~as of June 2, 2008. ~~Data collected or received between June 2, 2008 and July 19, 2010 is presented in Appendix H.~~

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J – The associated numerical value is an estimated quantity.

N – Presumptive evidence of presence of organic compound; identification of the compound is not definitive. The N qualifier is used in combination with the J qualifier.

U – The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

In certain cases, concentrations of closely–related analytes were added together to create a group sum. When calculating group concentrations for this in-river contaminant distribution evaluation, a value of zero was used for non-detected concentrations on an individual sample basis. 2,3,7,8- TCDD TEQ values for dioxin-like PCB congeners and PCDD/Fs were calculated using WHO 2005 TEFs for mammals[3] (Van den Berg et al. 2006). Benzo(a)pyrene equivalent (BaPEq) values used to represent carcinogenic PAHs (cPAHs) were calculated using PEFs provided in EPA (1993). Tables in Appendix D1.6 present the constituent concentrations used in each group sum. Further information on summing methods is provided in Appendix A.

5.1 SELECTION OF INDICATOR CONTAMINANTS

Contaminants of interest (COIs) are contaminants expected to be present at a site based on a review of site information. Numerous chemical ~~and physical~~ parameters were identified ~~as COIs~~ for the Study Area from the site assessment and were subsequently analyzed and detected in sampled various media ~~(Table 5.0-1)~~. Summary statistics for all COIs are presented by media for each river reach in Appendix D. ~~Owing to the distribution of contaminant sources and the dynamic nature of the Willamette River, COIs have become comingled to some extent throughout the Study Area.~~ Table 5.1-1 presents the COIs detected in the various media (sediment, water and biota) of the river.

Due to the large number of COIs detected at the site in various media, this section of the RI will focus on a subset of the contaminants - designated as indicator contaminants - to facilitate a clear and practical presentation of the ~~nature and~~ distribution of contamination in the Study Area ~~for the RI~~. It should be noted that additional contaminants beyond the indicator contaminants presented in this section are present at the site at concentrations that pose unacceptable risk to human health and the environment, and by limiting the discussion of contaminants in this section in no way limits the contaminants that will be considered in the FS or cleanup decisions made by EPA.~~an IC list~~

Indicator contaminants were~~as~~ identified using a screening process (Table 5.1-2) that first compared the detected COIs at the site (Table 5.1-1) with those contaminants posing unacceptable risk to human health and the environment ~~from the extensive list of~~

[3] The World Health Organization (WHO) has provided a list of 12 dioxin-like congeners: ~~which are~~ PCB-77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189.

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Commented [A1]: Nature and extent refers to the source from which the release occurs to the areal extent of that release in the environment. This section is not discussing nature and extent, but only in-river distribution of contamination.

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Commented [A2]: Table 5.0-1 does not accurately present COIs that were detected nor all media sampled. Incorporate EPA Table 5.1-1.

Commented [A3]: This is a conclusion statement: Conclusions are discussed in Section 10.

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~~COIs to represent the nature and extent of the range of contaminants that potentially pose risk to human health and the environment in sediment, surface water, TZW, and biota. Although additional COIs beyond the IC list may pose risk to human health and the environment and are present within the Study Area, the IC list was generated, in consultation with EPA[4] in the spring/summer of 2008, based on the chemicals that emerged from the Round 2 risk screening and preliminary risk evaluation process~~ and then considered~~ation of~~ the following ~~non-risk-based~~ factors:

- Frequency of detection—~~Chemicals~~Contaminants (pesticides) with a ~~high~~ frequency of detection less than 20% percent ~~(e.g., generally >50%)~~were not selected ~~were selected as an IC~~.
- Cross media comparisons—~~Preference was given to chemicals~~Contaminants that would ~~-~~allow comparisons across media were selected.
- Co-location of ~~Representative chemicals~~contaminants—Several ~~ICs~~contaminants were selected to represent ~~a suite of compounds~~other contaminants due to co-location of the contaminants (~~e.g.,~~for example, ~~BEHP was selected to represent the phthalate group~~arsenic, chromium, copper and zinc were selected to represent other metals).
- Widespread sources – Certain other contaminants with widespread sources in the harbor (e.g., metals, PAHs, and PCBs) were selected.
- Grouped contaminants – Some contaminants were grouped as one contaminant Contaminants that were grouped include PCBs, PCDD/Fs, DDx, and PAHs.
- Low exceedance of risk – Several contaminants did not contribute significantly to risk estimates (HQ<10 or risk at 10^{-6}) and were not selected.

The first screen indentified 35 key contaminants in the Study Area. An additional screen identified 14 indicator contaminants, which are the focus of further discussion in the RI. Although not discussed further in the RI, summary statistic tables, maps and figures by media are presented in Appendix D for the 21 "key contaminants" that were not identified as indicator contaminants.

- ~~EPA requests—EPA requested the inclusion of several additional chemicals for sediment and biota based on its review of the Round 2 Report (Integral et al. 2007). EPA also requested the inclusion of certain other chemicals with widespread sources in the harbor (metals, PAHs, and TPH) during the IC lists development discussions in 2008.~~

Commented [A4]: Appendix A5 has been deleted from the RI.

~~[4] As documented in Appendix A5, Attachments A4, A7, A9, and A11.~~

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~~Table~~ Table 5.1~~0~~-2~~2~~ identifies the ~~ICs~~[5] indicator contaminants selected by this process for ~~various uses~~further discussion in the RI.

Contaminants that were screened due to co-location were based either on one form of a contaminant representing another or on a correlation plot of the rank and location of the data sets. The basis for each contaminant screening due to co-location is presented in Table 5.1-3 and Figures 5.1-1 through 5.1-5.

Commented [A5]: These are the new correlation plots.

Data presentations identical to those provided in the following sections are also provided for physical parameters and other key COIs in Appendix D; however, there is no discussion or interpretation of the information.

~~This includes nature and extent for abiotic and biotic media chemicals (Section 5); loading, fate, and transport (Section 6); fate and transport modeling (part of FS); and the site-wide CSM (Section 10).~~

~~Once the baseline risk assessments were completed (the BHHRA is provided in Appendix F; the BERA in Appendix G), a list of contaminants posing potentially unacceptable risk was documented. These contaminants for the BHHRA and BERA are listed in Table 7-1 in Appendix F and Table 11-2 in Appendix G, respectively, and are included in Table 5.0-2. Additionally, chemicals in surface water and TZW sampling results that exceed tap water and surface water quality criteria/screening values (without taking into account any spatial or temporal averaging) are also included in Table 5.0-2; these contaminants will be carried into the FS for evaluation of chemical mobility. The water screening methods and results are provided in Appendix D3.3 and Anchor QEA (2011).~~

~~The nature and extent of four ICs or compound groups identified in the BHHRA and BERA as posing risk in the Study Area are believed to encompass the spatial extent of potentially unacceptable risks associated with the contaminants identified in the baseline risk assessments. These four chemicals, hereafter referred to as bounding ICs, are total PCBs, total PCDD/Fs (as both total dioxins/furans and dioxin/furan TCDD TEQ[6]), total DDx, and total PAHs. This is not intended to imply that other contaminants will not be evaluated in the FS and accounted for in the site remedy[7]. Other contaminants potentially posing risk are comingled with the bounding ICs, but because of their spatial distribution within the Study Area, only these bounding chemicals are discussed in detail in the Section 5 subsections that follow. For each medium, the nature and extent of the an additional set of ICs is also described in the~~

[5] ~~Contaminants for which PRGs are being developed through the FS process will not be finalized until late 2011. However, the LWG presumes that the ICs included in the RI will be consistent with the PRG list.~~

[6] ~~The dioxin/furan TCDD TEQ does not include dioxin-like PCB congeners.~~

[7] ~~These four COCs largely represent the areal extent of unacceptable risk to humans and wildlife (birds and mammals). Other COCs are associated with unacceptable risk, but generally within the areas represented by these four COCs. The exception may be where toxicity test results indicate unacceptable risk to the benthic invertebrate community, but no specific chemical has been associated with toxicity.~~

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~~following subsections. This set varies by media but it includes all chemicals that are the focus of the comprehensive cross-media and fate and transport evaluations presented in Section 10 (CSM) of this RI. This set of CSM chemicals was selected in consultation with EPA to provide a relatively complete picture of the distribution, transport, and fate of contaminants in the Study Area across a range of physical, chemical, and biological processes, as well as known and potential sources. Finally, tThe nature and extent data for the balance of the ICs COIs listed in Table 5.0-12 are presented on all tables, maps, and figures in Appendix D but not addressed in the narrative.~~

~~The following sections are organized by media and focus on the nature and extent of ICs in and immediately adjacent to the Study Area in sediments (Section 5.1), sediment traps (Section 5.2), surface water (Section 5.3), TZW (Section 5.4), and biota (Section 5.5).~~

Commented [A6]: This paragraph and the following paragraphs were incorporated into Section 5.0 discussion.

~~Depending on the medium examined, the nature and extent discussion is supported by a variety of tabular and graphical materials: 1) plan view and core maps for sediment showing the extent of each chemical's distribution, 2) summary statistics tables, 3) scatter plot graphs depicting chemical concentrations by river mile, and 4) bar charts and box-whisker plots for comparing values and distributions. Summary statistics for ICs are tabulated in the main text for bedded sediment (Tables 5.1-1 and 5.1-2), in-rivermobile sediment traps (Tables 5.2-1 through 5.2-4), surface water (Tables 5.3-2 through 5.3-7), and biota (Tables 5.5-1 and 5.5-2). Summary statistics for all parameters analyzed in each medium are presented in tables included in Appendix D. The entire RI database is presented in Appendix A3, and the updated RI database is presented in Appendix H, Attachment H-2.~~

~~For each IC, the following summary statistics are tabulated: the frequency of detection; the minimum, maximum, mean, median, and 95th percentile; and the station locations of the maximum values. Two sets of statistics are presented for each IC. One set reflects only detected values and the other set shows detected and undetected values combined. The statistics have been compiled separately for areas inside the Study Area (RM 1.9 - 11.8, ≤13 ft NAVD88, exclusive of the Multnomah Channel) and areas outside of it. Summary statistics for sediments include both point samples and composite samples to provide a general understanding of IC concentration distributions. The discussion of the nature and extent of ICs in media provided in the remainder of this section is based on statistics calculated for detected concentrations only.~~

~~Where specific results are cited in the text (i.e., the concentration of a sample, median and 95th percentile values) qualifiers associated with that result are also cited, with one exception. The qualifier "T" is not cited as it generally indicates that the result was mathematically derived through summing multiple results (e.g., total PCB congeners equal the sum of the PCB congener results). The "T" qualifier may also indicate that a result is an average of multiple results for a single analyte (e.g., field replicates) or that a result was selected for reporting in preference to other available results (e.g., for~~

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~~parameters reported by multiple methods). The following qualifiers are cited with the results:~~

~~**A** – Total value is based on a limited number of analytes.~~

~~**J** – The associated numerical value is an estimated quantity.~~

~~**N** – Presumptive evidence of presence of material; identification of the compound is not definitive.~~

~~**U** – The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.~~

~~**V** – Median or 95th percentile was obtained through interpolation of data.~~

~~In certain cases, concentrations of closely related analytes were added together to create a group sum. When calculating group concentrations for this nature and extent evaluation, a value of zero was used for non-detected concentrations on an individual sample basis; other analyte summing approaches were used in the risk evaluations presented in Appendices F and G of this report for the BHHRA and BERA, respectively.[8] The 2,3,7,8- TCDD TEQ values for dioxin-like PCB congeners and PCDD/Fs were calculated with WHO 2005 TEFs for mammals (Van den Berg et al. 2006). The bezo-a-pyrene equivant cPAH (BaPEq) values used to represent carcinogenic PAHs (cPAHs) were calculated using PEFs provided in EPA (1993). Tables in Appendix D1.6 present the constituent concentrations used in each group sum. Further information on summing methods is provided in Section 2.1.4Appendix A.~~

~~5.1~~5.2 INDICATOR ~~CHEMICALS~~ CONTAMINANTS IN BEDDED SEDIMENT

This section summarizes the surface and subsurface sediment data collected in the upriver reach, downtown reach, Study Area reach, and downriver reach. The locations of all surface and subsurface sediment samples in the ~~nature and extent~~RI data set are shown on Maps 2.2-1~~5,a – y and~~ 2.1~~ – 17, and~~ H2.3-1 and H2.3-2~~2- 2a – t~~. ~~The surface sediment data set includes all samples with intervals starting at 0 cm and extending to depths ranging to 40 cm bml.~~[9] The discussion of each contaminant focuses primarily on the following items:

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Commented [A8]: This is not a valid qualifier and must be removed from all tables.

Commented [A9]: These were moved to Appendix A...need to update with current figure numbers.

Commented [A10]: Since this sentence discusses the data set, it was moved to 5.2.1.

~~[8] For the RI, the summation methods use zero for non-detects within sums. This allows a clear presentation of detected results for assessment of nature and extent, avoiding bias presented by the detection limits. This also prevents high detection limits from creating confusion in the evaluation of nature and extent. For the BHHRA and BERA, the summation method uses one-half the detection limit for non-detects within the sums. This was the agreement with EPA.~~

~~[9] The functional definition of surface sediments for this site is 0–30 cm based on physical system studies. However, the recorded lower depth of a set of sediment samples (i.e., shallow cores that begin at the mudline) in the nature and extent data set reached to 40 cm. These samples were grouped with the surface data set, thus~~

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- A description of the data set for each contaminant, including sample counts, concentration range, and frequency of detection.
- A discussion of the surface and subsurface concentration distributions in the upriver reach, downtown reach, RI Study Area reach, and downriver reach. The RI Study Area reach is organized by eastern nearshore, western nearshore, and navigation channel subareas (Map 5.2-33) and discusses distributions within river mile reaches and hydrodynamic reaches (see discussion in Section 3).
- A discussion of the vertical trends in sediment concentrations and the relationship of subsurface sediment to surface sediment concentrations.

The sediment chemistry distributions are depicted in three graphical formats:

1. Surface plan-view concentration maps and subsurface core concentration maps (all reaches)
2. Scatter-plot graphs of surface and subsurface sediment (RM 0.8-12.2)
3. Histograms comparing mean surface and subsurface concentrations by river mile (RM 0-11.8)

Core plots showing a higher level of detail have been produced for the following indicator contaminants:

- Total PCBs
- Total DDx
- TCDD TEQ
- Total PAHs.

Additionally, more detailed core plots were developed for total cPAHs and presented in Appendix D1.2. More detailed core plot maps were developed for these particular contaminants because they are more prevalent throughout the Study Area.

Surface Chemistry Maps: The plan-view concentration maps present all surface sample data using color-coded dots that correspond to a concentration scale for that particular chemical. The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps were based on the frequency distributions (i.e., natural breaks) in the data set for these contaminants and have no environmental significance. Non-detected concentrations are differentiated from detected concentrations on the surface maps by a dot in the center of the sample symbol ⊙. The maps include data points from locations that were dredged or capped subsequent to the

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Commented [A11]: Appendix H3 surface maps will replace surface maps in this section.

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Commented [A12]: Appendix D1.2 maps will replace subsurface maps for Total PCBs, Total DDx, TCDD TEQ, Total PAHs, and Total cPAHs. Appendix H3 subsurface maps for each indicator contaminant will be added to end of each series of subsurface maps in Section 5 as "n" and "o".

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~~extending the maximum depth for the surface horizon to 40 cm. Core samples that extended from the mudline to depths greater than 40 cm were grouped with the subsurface sediment data set.~~

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collection of the sample(s) shown by a circle centered around the sample symbol ◎.[10,11] Data from these areas are presented to show spatial patterns of chemicals from a historical, pre-dredge perspective. In addition, the surface maps include histograms showing the distributions and frequencies of the detected and non-detected results. Data from all samples shown on the maps are included in the histograms.

Subsurface Core Maps: The core maps show the distribution of contaminants with depth at each of the subsurface sediment sampling stations (these maps also include the surface sample data). Inset maps for densely sampled core areas are provided in most cases. In these maps, the actual core station is marked with a triangle △. The core segment divisions displayed on the maps are scaled to the thickness of each sample interval. Note that these maps do include cores from locations that were subsequently dredged or capped, as indicated on the maps. Cores taken post-dredging are also included on the maps. The subsurface concentration maps do not indicate samples where concentrations are based on partial sums (i.e., A-qualified data; the few cases where data are based on partial sums from non-LWG studies).

Scatter Plots: Scatter plots present the distribution of detected contaminants in surface and subsurface sediment per river mile. The data are presented in a log scale (by order of magnitude) to facilitate in the discussion on distribution and to fit all the data onto one plot due to the vast range in concentrations detected. To aid in differentiating potential concentration trends in the Study Area, the data in these plots are further separated into eastern nearshore, western nearshore, and navigation channel stations as defined by the federal navigation channel boundary (Map 5.2-33). Data collected in Multinomah Channel is presented with the western shore data and is identified using a different symbol. Likewise, data collected in Swan Island Lagoon is presented with the eastern shore data and identified with a unique symbol. Unlike the plan-view maps, the scatter plots do *not* include data for samples from locations that have been subsequently dredged or capped.

Histograms: The histograms compare the average surface and subsurface sediment chemical concentrations for the indicator contaminants on subarea basis. The y-axis in the plots is centered on a value of 0, which represents the vertical horizon (40 cm bml) between the surface and subsurface samples. Bars extending downward from the y-axis depict the subsurface mean values. Bars extending upward show the surface sediment means. Subareas included east, navigation channel, and west zones for each river mile in the Study Area, as well as Multnomah Channel, Swan Island Lagoon, downstream reach (RM 0–2), upriver reach (RM 15.3-26), and downtown reach (RM 11.8-15.3).

[10] For example, all data shown for locations *within the capped area* at the M&B site (see Maps 2.2-1i and 2.2-2i) are from surveys completed between 1999 and 2002, prior to capping. These data are shown on the surface and subsurface core plan-view maps and included in the map histograms; however, they are not included in the other sediment data presentations (i.e., scatter plots, and histograms~~, and stacked bar charts, discussed below~~).

[11] Surface interval sample locations G088, G087, and G091 collected in 2004 in the International Terminals Slip were dredged subsequent to sampling. These locations were resampled in 2005 at C088, C087, and C091.

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Mean concentrations were also calculated for each zone in the entire Study Area (see leftmost column in each figure).

These histograms are useful in providing a visual summary of spatially averaged surface/subsurface trends throughout the Study Area. However, some caution is needed in interpreting the trends due to the biased nature of the RI sampling program (i.e., subsurface core samples were generally focused on known areas of contamination, whereas surface samples were distributed more widely). Further, highly contaminated areas may not necessarily be contained within a specific river mile, but rather partially overlap two adjacent river miles. Consequently, these histograms should be examined in conjunction with the subsurface core maps in evaluating surface to subsurface trends for a specific contaminant and subarea. This is particularly true for the relative low density PCDD/F data presented in Figure 5.2-8.

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~~5.13.1~~5.2.1 Sediment Data Set

The sediment RI data set is composed of all Category 1 LWG and non-LWG data (refer to Table D1.3-1) collected within the down reach (RM 0 to 1.9), the RI Study Area reach (RM 1.9 to 11.8), the downtown reach (RM 11.8 to 15.3), and the upriver reach (RM 15.8 to 26), from May 1997 to July 2010. ~~The sediment RI data set is composed of all Category 1 LWG and non-LWG data collected within the Study Area (below +13 ft NAVD88) from May 1997 to December 2007. Sediments collected below +13 ft NAVD88 include both subaqueous sediment and beach sediment. Sediment data are used to characterize contaminant distribution and potential source effects, to provide data necessary for the risk assessments, to provide data for the FS, and to refine the understanding of the physical dynamics of the river system.~~

The surface sediment data set includes all samples with intervals starting at 0 cm and extending to depths ranging to 40 cm bml. The subsurface data set includes all samples collected at depths greater than 40 cm bml. The Upriver reach is dynamic and the channel is coarse-grained with finer-grained sediments generally restricted to small off-channel areas (Map 5.2-50), thus, most of the main channel above RM 20 could not be sampled with a grab sampler because the river bed is cobbled or hard. Further, there are limited subsurface samples due to the outcropping of basalt in the upper river reach.~~Summary statistics for grain size, TOC, and ICs in the surface and subsurface sediment samples from the Study Area are presented in Tables 5.1-1 and 5.1-2; the full data set is provided in Appendix D1.3. . These summary statistics do *not* include results from locations that were dredged or capped subsequent to sample collection. However, post-dredged sediment samples are included in the summary statistics.~~

Summary statistics for indicator contaminants, percent fines, and TOC in the surface and subsurface sediment samples for the entire RI Study Area reach are presented in Tables 5.2-1 and 5.2-2. The data from the RI Study Area were segregated into the eastern shore, navigation channel, and western shore and are presented by river mile in

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Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. These summary statistics do *not* include results from locations that were dredged or capped subsequent to sample collection. However, post-dredged sediment samples are included in the summary statistics. Similar summary statistics are presented for the Upriver reach in Tables 5.2-15 and 5.2-16, the Downtown reach in Tables 5.2-17 and 5.2-18, and the Downstream~~river~~ reach in Tables 5.2-19 and 5.2-20.

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~~5.13.2~~ Indicator Chemicals in Sediment

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~~The IC list for sediment is presented in Table 5.0-2. The selection of ICs was guided by the considerations detailed in Section 5.0. A total of 34 individual analytes and calculated chemical sums were identified as ICs for sediment. They are organized as follows:~~

- ~~PCBs~~

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~~Total PCBs*~~

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~~PCB TEQ (ND=0)~~

- ~~PCDD/Fs~~

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~~Total PCDD/Fs* and TCDD TEQ (ND=0)*~~

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- ~~DDx~~

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~~Total DDx (sum of 2,4'- and 4,4'- DDD, DDE, DDT)*~~

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~~– Total of 2,4'- and 4,4'- DDT~~

~~– Total of 2,4'- and 4,4'- DDE~~

~~– Total of 2,4'- and 4,4'- DDD~~

- ~~PAHs~~

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~~Total PAHs*~~

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~~Total cPAH BaPEq values~~

~~Total LPAHs~~

~~Total HPAHs~~

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- ~~Phenanthrene~~
- ~~Naphthalene~~
- ~~BAP~~
- ~~Petroleum Hydrocarbons~~ — **Formatted:** Body Text
- ~~TPH~~ — **Formatted:** Body Text, No bullets or numbering
- ~~TPH - Diesel-range hydrocarbons (DRH)~~
- ~~TPH - Residual-range hydrocarbons (RRH)~~
- ~~SVOCs~~ — **Formatted:** Body Text
- ~~BEHP*~~ — **Formatted:** Body Text, No bullets or numbering
- ~~Butylbenzyl phthalate~~
- ~~Pentachlorophenol~~
- ~~Hexachlorobenzene~~
- ~~Pesticides~~ — **Formatted:** Body Text
- ~~Total chlordanes*~~ — **Formatted:** Body Text, No bullets or numbering
- ~~gamma-Hexachlorocyclohexane (HCH)~~
- ~~Aldrin*~~
- ~~Dieldrin*~~
- ~~Metals~~ — **Formatted:** Body Text
- ~~Arsenic*~~ — **Formatted:** Body Text, No bullets or numbering
- ~~Cadmium~~
- ~~Chromium*~~
- ~~Copper*~~
- ~~Lead~~

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~~Mercury~~

~~Nickel~~

~~Zinc*~~

- ~~Organometallic Compounds~~

~~TBT*.~~

~~This section focuses on the distribution of a subset of 13 ICs in surface and subsurface sediment within the Study Area, which are indicated with an asterisk (*) in the above list (total PCDD/Fs and TCDD TEQ are grouped as one chemical in this count). Although numerous contaminants that potentially pose risk to human health or the environment are comingled across the site, these 13 ICs were selected, in consultation with EPA, based on the preliminary risk evaluations and other site information, and match the contaminants presented and discussed in the site-wide CSM (Section 10). Of these, four contaminant groups – total PCBs, total PCDD/Fs (including TCDD TEQ), total DDx, and total PAHs – have been identified as bounding ICs based on the risk evaluations and their nature and extent are discussed in depth here. The discussion focuses primarily on the following items:~~

- ~~A description of the data set for each contaminant, including sample counts, concentration range, and frequency of detection.~~

- ~~A discussion of the surface and subsurface concentration distributions in the Study Area organized by eastern nearshore, western nearshore, and navigation channel subareas.~~

- ~~Additional information is provided for the four bounding ICs:~~

  - ~~The vertical trends in sediment concentrations~~

  - ~~The relationship of subsurface sediment to surface sediment~~

  - ~~The nature and composition of these complex chemical groups and distribution patterns.~~

~~The discussion of the other 9 ICs in the subset is less comprehensive, omitting the data set description and referring instead to maps, tables, and figures to provide a complete picture of the distribution of these contaminants. The data for the remaining 21 sediment ICs is presented in Appendix D1. In Section 10, contaminant distributions across abiotic and biotic media and in relation to specific potential sources are presented in more detail for the subset of 13 ICs.~~

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5.13.55 Description of Sediment Presentation Tools

The sediment RI data set is composed of all Category 1 LWG and non-LWG data collected within the Study Area (below +13 ft NAVD88) from May 1997 to December 2007July 2010. The sediment chemistry distributions are depicted in five graphical formats: surface plan-view concentration maps and subsurface core concentration maps (Maps 5.21-1 through 5.21-28), scatter-plot graphs (Figures 5.21-1 through 5.21-32), and histograms and stacked bar charts (Figures 5.1-33 through 5.1-457). At EPA's request, cCore plots showing a higher level of detail have been produced for the following ICs:

- Total PCBs
- Total DDx
- TCDD TEQ
- Total PAHs
- Total cPAH BaPEq values.

These more detailed core plot maps are presented in Appendix D1.2.

Maps and scatter-plot graphs of surface and subsurface concentrations for the remaining 21 ICs, plus percent fines and TOC, are included in Appendices D1.1 and D1.4, respectively. Appendix D1.3 provides statistical summaries of all sediment analytes.

Surface Chemistry Maps: The plan-view concentration maps present all surface sample data using color-coded dots that correspond to a concentration scale for that particular chemical. Non-detected concentrations are differentiated from detected concentrations on the surface maps by a dot in the center of the sample symbol (i.e. ⊙). The maps include data points from locations that were dredged or capped subsequent to the collection of the sample(s) (shown by a circle centered around the sample symbol [i.e., ◎]).[12,13] Data from these areas are presented to show spatial patterns of chemicals from a historical perspective. In addition, the surface maps include histograms showing the distributions and frequencies of the detected and non-detected results. Data from all samples shown on the maps are included in the histograms.

The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps (e.g., the threshold value for the red labels) were based on the frequency distributions (i.e., natural breaks) in the historical data set for these compounds and as

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[12] For example, all data shown for locations *within the capped area* at the M&B site (see Maps 2.2-1i and 2.2-2i) are from surveys completed between 1999 and 2002, prior to capping. These data are shown on the surface and subsurface core plan-view maps and included in the map histograms; however, they are not included in the other sediment data presentations (i.e., scatter plots, histograms, and stacked bar charts, discussed below).

[13] Surface interval sample locations G088, G087, and G091 collected in 2004 in the International Terminals Slip were dredged subsequent to sampling. These locations were resampled in 2005 at C088, C087, and C091.

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approved or modified by EPA for use in the Programmatic Work Plan. These concentration range intervals were also used in the Round 2 Report.

Subsurface Core Maps: The core maps show the distribution of ICs with depth at the subsurface sediment sampling stations (these maps also include the surface sample data). Inset maps for densely sampled core areas are provided in most cases, unless the core samples in these areas were archived (i.e., for possible future chemical analysis). In these maps, the actual core station is marked with a triangle (i.e., △). The core segment divisions displayed on the maps are scaled to the thickness of each sample interval. Note that these maps do include cores from locations that were subsequently dredged or capped, as indicated on the maps. Cores taken post-dredging are also included on the maps. The subsurface concentration maps do not indicate samples where concentrations are based on partial sums (i.e., A-qualified data; the few cases where data are based on partial sums are from non-LWG studies).

Scatter Plots: Scatter plots of the distribution of analytes in surface and subsurface sediment per river mile are presented in Figures 5.1-1 through 5.1-32, and in Appendix D1.4. To aid in differentiating potential concentration trends, the data in these plots are further separated into eastern nearshore, western nearshore, navigation channel, and Multnomah Channel stations as defined by the federal navigation channel boundary. The areas falling into these categories are shown in Map 5.1-29. Unlike the plan-view maps, the scatter plots do *not* include data for samples from locations that have been subsequently dredged or capped.

Histograms: Histograms were developed to supplement the subsurface core maps and support examination of vertical trends in chemical concentrations with depth in the sediment column. The histograms compare the absolute magnitude of the ratios of surface and subsurface sediment chemical concentrations for the bounding ICs on subarea basis (e.g., RM 8-9 west of channel; see Figures 5.1-33, 5.1-39, 5.1-42, and 5.1-45). The ratios were calculated by dividing the mean of all detected surface sample concentrations in a given subarea by the mean of all detected subsurface core interval samples in that subarea. The absolute magnitude of the ratios is plotted on the histograms (i.e., where the subsurface mean is greater than the surface mean, the inverse of the ratio is plotted). The actual surface and subsurface concentrations for individual samples by river mile are shown on the scatter plots (Figures 5.1-1 through 5.1-32 noted above), and as with the scatter plots, the histograms do *not* include data from dredged or capped samples.

The y-axis in the plots is centered on a value of 0, which represents no numerical difference between the mean surface and subsurface concentrations for a given subarea. Values extending downward from the y-axis indicate areas where the mean of subsurface values exceeds the surface mean. Bars extending upward show where the surface sediment means are greater. The y-axis value indicates the absolute magnitude of the differences between the surface and subsurface means. In some instances, a ratio could not be determined because only surface sediments were analyzed for the

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bounding ICs in that subarea. Subareas included east, navigation channel, and west zones for each river mile in the Study Area, as well as downstream (RM 0-2), Multnomah Channel, and Swan Island Lagoon. Mean concentrations were also calculated for the Study Area as a whole (see leftmost column in each figure).

These histograms are useful in providing a visual summary of spatially averaged surface/subsurface trends throughout the Study Area and, therefore, for identifying ongoing versus historical sources of contamination. However, some caution is needed in interpreting the trends due to the biased nature of the RI sampling program (i.e., subsurface core samples were generally focused on known areas of contamination, whereas surface samples were distributed more widely). Consequently, these histograms should be examined in conjunction with the subsurface core maps in evaluating surface to subsurface trends for a specific IC and subarea. This is particularly true for the relative low density PCDD/F data plotted in Figure 5.1-39, where a single extreme data point can skew the calculated ratio.

Stacked Bar Charts: Stacked bar charts are designed to reveal potential distinctive patterns in the relative abundance of bounding IC components (e.g., homologs, isomers). The analyte components are shown in the stacked bars as a percent of the total concentration, while the total concentration of the IC is displayed as a line on a logarithmic scale. Station location labels are provided on the x-axis, and river mile is indicted on the secondary x-axis along the top of the chart. Subsurface figures display only the sample interval with the maximum concentration of the analyte, per core station location. The stacked bar charts do *not* include data from dredged or capped samples.

Commented [A22]: These can be moved to Appendix D with discussion of patterns and trends.

Any patterns apparent in the stacked bar charts must be interpreted with caution. Changes in chemical composition and apparent trends shown by the bar charts may be indicative of significant patterns (e.g., distinctive source contributions), or they may be within the range of normal data variability. Further, it should be kept in mind that the display of constituent components as a percentage of the total may, in some cases, amplify the visual impact of what are in fact small-scale changes in sample composition. It is important to emphasize that source identification and allocation are complex multivariate problems. The pattern shifts discussed in the following sections based on stacked bar chart presentations may be suggestive, but cannot be interpreted directly as or attributed to localized sources. Such a characterization would require rigorous quantitative forensic analysis, which is outside the scope of this RI/FS.

5.13.73 Sampling Methods

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LWG surface sediment samples were collected in a consistent, repeatable manner with a stainless steel, 0.3 m^2 hydraulic power grab sampler. The maximum penetration of the power grab sampler was approximately 30 cm. Non-LWG surface samples were collected using a variety of sampling devices, including ponar samplers, power grabs, Eckman samplers, box cores, and spoons. A limited number of non-LWG surface

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~~samples were collected from the mudline to depths of 30 to 40 cm bml, and these data are also included in the RI surface sediment data set.~~

~~Subsurface sediment was collected by the LWG using a customized vibracorer equipped with either 14-ft or 20-ft core tube. Non-LWG subsurface samples were collected by a variety of methods and depths, the most common being a vibracore, followed by a "driven tube." The driven tube could include the vibracore, impact, or gravity methods. Other coring samplers included gravity corer, macro-core sampler, impact corer, hand core, split-spoon sampler, Mudmole™, and steam auger.~~

~~5.13.7~~5.2.2 Total PCBs in Surface and Subsurface Sediment ~~(Congeners and Aroclors)~~

~~This subsection summarizes the surface and subsurface distribution of total PCB concentrations in the Study Area, compares the PCB congener and Aroclor concentrations, and discusses PCB homolog and Aroclor patterns across the Study Area. For the purpose of sediment characterization, total PCB congener concentrations represent the sum of detected congener concentrations in a sample. In cases where no congeners were detected, the single highest detection limit of all congeners analyzed is used to represent the total value. Similarly, total PCB Aroclor values reflect the sum of detected Aroclors in a sample.~~

~~To simplify characterization of PCBs in the Study Area, the total PCB congener and total Aroclor data were combined into a single data set of total PCBs. These total PCB data were used to create Maps 5.1-1 and 5.1-2a–m. The total PCB data set consists of the result for total PCB congeners for each sample when available (with one exception), and the result for total Aroclors when no total PCB congener data are available. Priority was given to PCB congener data based on the greater specificity and accuracy of the laboratory method for congeners (see Appendix D1.5). The exception is that total Aroclor data were selected to represent total PCBs for Round 2A beach sediment samples because the beach samples were only analyzed for coplanar PCB congeners, which constitute a small fraction of the total PCBs. Congener analyses for the remaining LWG sediment samples included all 209 congeners. Total PCB concentration data for the Study Area are available for 1,184 surface and 1,325 subsurface samples. Most of the PCB data are based on Aroclor analyses (Tables 5.1-1 and 5.1-2). Maps 5.1-30 and 5.1-31 display the locations of surface and subsurface sediment samples analyzed for PCBs and indicate whether PCB congener data, Aroclor data, or both are available.~~

The distribution of ~~maximum~~ total PCB concentrations at each surface sediment sampling station throughout the Study Area is depicted on ~~Map~~ Map 5.2~~1~~-1; concentrations with depth at subsurface stations are depicted on ~~Maps~~ Map 5.2~~1~~-2a–o~~m~~. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are

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presented. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-3a-ff.

Scatter plots of the total PCB data set for surface and subsurface sediment in the Study Area are presented on ~~–~~Figures 5.2-1 and 5.2-2~~The complete data set for surface and subsurface sediment in the Study Area is plotted on scatter plots presented in Figures 5.1-1 and 5.1-2~~, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

~~Scatter plots for total PCB congeners and Aroclors are shown in Figures 5.1-3 through 5.1-6.~~ S~~The s~~ummary statistics ~~values shown in Tables 5.1-1 and 5.1-2~~ for total ~~Aroclors and total~~ PCB ~~congener~~s in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2~~ indicate overall higher sample concentrations of total PCB when summing congeners~~. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PCB data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only~~of~~ detected values and for combined detect and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-3.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-36. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12, number of data points by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16, number of data points by order of magnitude are provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20, number of data points by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and nondetects). ~~The higher concentrations measured by summing congeners are not a result of differences in laboratory methodology, but rather are attributable to a more targeted sample selection process, i.e., samples selected for PCB congener analysis frequently targeted areas known or suspected to have relatively high PCB contamination.~~

~~5.13.76.1 Total PCB Congener and Aroclor Correlation~~

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~~The relationship between total PCB congener and total Aroclor concentrations is discussed in detail in Appendix D1.5. Both methods represent the total PCB concentrations well, and summed total PCB concentrations are fairly comparable between methods in most cases. The surface sediment correlation (coefficient of determination) between same-sample congener and~~

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~~Aroclor totals was $r^2 = 0.761$, and the subsurface correlation was $r^2 = 0.476$. Plots of these regressions are presented in Appendix D1.5. For all data (sediment, sediment trap, and biota), r^2 was 0.70. PCB totals based on congeners and Aroclors did not correspond well for 11 sediment samples (i.e., an order of magnitude difference between the total congener and total Aroclor results); these are also described in Appendix D1.5. The evaluation of the relationship between PCB congener and PCB Aroclor concentrations in Appendix D1.5 indicates that total Aroclor data may overpredict total PCB congeners in concentrations below ~750 µg/kg total Aroclors and may result in underprediction above 750 µg/kg.~~

~~PCB congener data better represent total PCB concentrations than Aroclor data, as the congener method is less affected by "weathering," non-PCB interferences, and subjective Aroclor identifications. For this reason, in this report, total PCB congener concentrations are given priority over total Aroclor concentrations when total PCB congener data exist for any given sample. Because measured total PCB concentrations are fairly comparable between methods in most cases (especially when measurement error is considered), it is useful to use Aroclor concentrations when no PCB congener data exist. Combining the PCB data in this way provides greater spatial and temporal coverage than using congener data alone.~~

5.2.2.1 Total PCB Data Set

The surface and subsurface data set includes PCBs analyzed for both Aroclors and congeners. For the purpose of sediment characterization, total PCB congener concentrations represent the sum of detected congener concentrations in a sample. In cases where no congeners were detected, the single highest detection limit of all congeners analyzed is used to represent the total value. Similarly, total PCB Aroclor values reflect the sum of detected Aroclors in a sample.

The relationship between total PCB congener and total Aroclor concentrations is discussed in detail in Appendix D1.5. The coefficient of determination between same-sample congener and Aroclor totals in surface sediment was $r^2 = 0.761$, and $r^2 = 0.476$ for subsurface sediment. Plots of these regressions are presented in Appendix D1.5. For all data (sediment, sediment trap, and biota), r^2 was 0.70. PCB totals based on congeners and Aroclors did not correspond well for 11 sediment samples, an order of magnitude difference was observed between the total congener and total Aroclor results, as described in Appendix D1.5. The evaluation indicates that total Aroclor data may overpredict total PCB congeners in concentrations below ~750 µg/kg total Aroclors and may underpredict above 750 µg/kg. For this reason, PCB congener data was determined to better represent total PCB concentrations than Aroclor data, as the congener method is less affected by "weathering," non-PCB interferences, and subjective Aroclor identifications.

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In this report, total PCB congener concentrations are given priority over total Aroclor concentrations when total PCB congener data exist for any given sample, based on the greater specificity and accuracy of the laboratory method for congeners. Because measured total PCB concentrations are fairly comparable between methods in most

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cases, it is useful to use Aroclor concentrations when no PCB congener data exist, which represent the majority of the samples. Combining the PCB data in this way provides greater spatial and temporal coverage than using congener data alone due to the lack of congener data available.

The summary statistics values shown in Tables 5.2-1 and 5.2-2 for total Aroclors and total PCB congeners indicate overall higher sample concentrations of total PCB when summing congeners. The higher concentrations measured by summing congeners are not a result of differences in laboratory methodology, but rather are attributable to a more targeted sample selection process, in which samples selected for PCB congener analysis frequently targeted areas known or suspected to have relatively high PCB contamination.

Consequently, the total PCB data set consists of the result for total PCB congeners for each sample when available[14], and the result for total Aroclors when no total PCB congener data are available for a particular sampling location. Congener analyses for the remaining LWG sediment samples included all 209 congeners. Total PCB concentration data for sediment within the Study Area are available for 1,318 surface and 1,543 subsurface samples. Most of the total PCB data are based on Aroclor analyses (Tables 5.2-1 and 5.2-2). Maps 5.2-4 and 5.2-5 display the locations of surface and subsurface sediment samples analyzed for PCBs and indicate whether PCB congener data, Aroclor data, or both are available.

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~~5.13.76.2~~ Total PCBs in Surface Sediment

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Upriver Reach (~~RM~~ RM 15.3 to 28.4)

Total PCBs were detected in 42 of 81 surface sediment samples within the Upriver reach (frequency of detection 52 percent). Detected concentrations ranged from 0.29J µg/kg to 31 µg/kg (Table 5.2-11). Total PCBs (Tables 5.2-13 and 5.2-14) were at or greater than 10 µg/kg in 4 samples, between 1 µg/kg and 10 µg/kg in 34 samples, and less than 1 µg/kg in 4 samples. The mean total PCB concentration in this reach is 4.48 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PCBs were detected in 195 of 265 surface sediment samples within the Downtown reach (frequency of detection 74 percent). Detected concentrations ranged from 0.798J µg/kg to 19,700 µg/kg (Table 5.2-15a and Map 5.2-36). Concentrations reported were greater than 10,000 µg/kg in three samples, between 1,000 and

[14] The exception is that total Aroclor data were selected to represent total PCBs for Round 2A beach sediment samples because the beach samples were only analyzed for coplanar PCB congeners, which constitute a small fraction of the total PCBs.

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10,000 µg/kg in 12 samples, between 100 and 1,000 µg/kg in 51 samples, between 1 and 10 µg/kg in 47 samples, and less than 1 µg/kg in one sample (Tables 5.2-17 and 5.2-18).

The majority of samples with concentrations greater than 1,000 µg/kg were located along the western shoreline between RM 13.5 and 14.1, which is the location of the Zidell facility. In 2011, a remedial action was conducted at the Zidell facility under ODEQ authority. Within the area addressed by the remedial action, total PCBs were detected in 111 surface sediment samples (frequency of detection of 73 percent). Concentrations reported ranged from 1.27 µg/kg to 19,700 µg/kg, with a mean of 1,320 µg/kg (Table 5.2-15c). When the data for the Zidell facility is removed from the downtown reach data set (Table 5.2-15b), total PCB concentrations in surface sediment ranged from 0.798J µg/kg to 4,200 µg/kg, with a mean of 108 µg/kg.

Study Area Reach (RM 1.9 to 11.8)

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Total PCBs were detected in 80 percent of ~~940~~ surface sediment samples (1,052 detections) within the Study Area ~~(detection frequency of 79 percent),). with c~~Concentrations reported ~~ranging~~ ranged from 0.851-J µg/kg to 35,400 µg/kg (Table 5.2~~1~~-1~~).), Ninety-five percent of the concentrations in surface samples were less than 641 V µg/kg.~~

~~Total PCB concentrations in surface sediment~~and varied ~~along~~ throughout the Study Area (Figure 5.2-1~~2~~). This information is presented on Map 5.2-1, ~~With few exceptions, concentrations were generally less than 100 µg/kg throughout the navigation channel, whereas many areas in the nearshore zones contained concentrations greater than 100 µg/kg in surface samples (Figure 5.1-1). T~~total PCB concentrations exceeding 1,000 µg/kg~~in the scatter plots~~ are indicated in red on Map 5.2-1~~1-1~~.

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Several~~A~~ prominent concentration peaks, defined as greater than 1,000 µg/kg ~~in the surface data -~~, are present in ~~from~~ the eastern nearshore zone~~-~~: RM 1.9-RM 4, RM 6-7, Swan Island Lagoon, and RM 11-11.8 (Figure 5.2-1). Mean total PCB concentrations in these areas are: 663 µg/kg at RM 1.9-3, 369 µg/kg at RM 3-4; 223 µg/kg at RM 6~~--~~7, 373 µg/kg in Swan Island Lagoon; and 495 µg/kg at RM 11-11.8 (Table 5.2-3).

The highest total PCB concentrations along the western side of the river are found in the western nearshore zone from RM 8-10; including ~~at RM 8.8, where~~ the highest detected surface concentration (35,400 µg/kg) ~~in the data set was detected~~ at Station G453 (RM 8.8 ~~(Station G453~~). ~~–~~ Mean total PCB concentrations in this area are 978 µg/kg at RM 8-9 and 341 µg/kg at RM 9-10 (Table 5.2-7).

The highest concentrations found in the navigation channel zone are at RM 11 to 11.8, which is linked with the contamination noted along the eastern nearshore area (Map

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5.2-1). The maximum detected concentration in this area was 5,900 µg/kg, with a mean concentration 292 µg/kg (Table 5.2-5).

Total PCB concentrations greater than 10,000 µg/kg were found in only two locations; in the western nearshore zone at RM 8.8, and in Swan Island Lagoon (Tables 5.2-9 and 5.2-10). Total PCB concentrations between 1,000 and 10,000 µg/kg were reported in 37 samples, all within the areas described above. Overall, concentrations greater than 1,000 µg/kg account for four percent of detected results (39 samples), 19 percent were between 100 and 1,000 µg/kg (203 samples), 59 percent (621 samples) were between 10 and 100 µg/kg, 18 percent (188 samples) were between 1 and 10 µg/kg, and one sample was detected at a concentration less than 1 µg/kg (Map 5.2-1).

Downstream Reach (RM 0 to 1.9)

Total PCBs were detected in 16 of 25 surface sediment samples within the Downstream reach. Concentrations reported ranged from 1.03J µg/kg to 410 µg/kg (Table 5.2-19), with a single result greater than 1,000 µg/kg (Tables 5.2-21 and 5.2-22). Overall, concentrations between 100 and 1,000 µg/kg account for 38 percent of detected results (8 samples), 52 percent were between 10 and 100 µg/kg (11 samples), and one between 1 and 10 µg/kg. The mean total PCB concentration in this reach is 34 µg/kg.

~~5.13.76.3~~5.2.2.3 Total PCBs in Subsurface Sediment

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Upriver Reach (RM 15.3 to 28.4)

Three subsurface sediment samples were analyzed for total PCBs within the Upriver reach between RM 15.4 and 16. All results were reported as nondetect, with a maximum reporting limit of 11 µg/kg (Table 5.2-12).

Downtown Reach (RM 11.8 to 15.3)

Total PCBs were detected in 59 of 110 subsurface sediment samples within the Downtown reach. Concentrations reported ranged from 1.4J µg/kg to 610 µg/kg (Table 5.2-16a) with a mean concentration of 92 µg/kg. Within this reach, 14 percent (15 samples) of the reported results were between 100 and 1,000 µg/kg, 44 percent (31 samples) were between 10 and 100 µg/kg, and 22 percent (13 samples) were between 1 and 10 µg/kg. All detected results were greater 1 µg/kg (Tables 5.2-17 and 5.2-18). Only two subsurface samples were collected from the vicinity of the Zidell facility, the reported concentrations were 140 µg/kg and 190 µg/kg.

Study Area Reach (RM 1.9 to 11.8)

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Total PCBs were detected in 939~~862~~ subsurface samples within the Study Area (detection frequency of 6~~1~~5 percent), with detected concentrations ~~and~~ ranginged from 0.00138 J µg/kg to 36,800 µg/kg (Table 5.2~~1~~-2).

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Similar to surface sediment, total PCB concentrations in the subsurface also varied within the Study Area. ~~(Figure 5.1-2; Maps 5.1-2a–m).~~

Several areas of higher concentrations (greater than 1,000 µg/kg) in the subsurface data are identified in the eastern nearshore zone (Figure 5.2-2, Maps 5.2-2a–o and 5.2-3a-ff) from RM 1.9-4, RM 5-6, Swan Island Lagoon, and RM 11-11.8. Mean concentrations in these areas are: 521 µg/kg at RM 1.9-3, 1,530 µg/kg at RM 3-4, 369 µg/kg at RM 5-RM 6; 560 µg/kg in Swan Island Lagoon; and 464 µg/kg at RM 11-11.8 (Table 5.2-4).

An area of high total PCB concentrations is located in the western nearshore zone from RM 7-10. The highest subsurface concentration of 36,800 µg/kg was reported in the sample from Station C455 at 30–153 cm bml. Mean total PCB concentrations in this area are 177 µg/kg at RM 7 - RM 8, 931 µg/kg at RM 8-9, and 424 µg/kg at RM 9-10 (Table 5.2-8).

The highest reported concentrations in the Navigation Channel are at RM 10-11.8. The total area is larger than and encompasses the area of higher concentrations reported in surface sediment. Mean total PCB concentrations in this are: 443 µg/kg at RM 10-11 and 107 µg/kg at RM 11-11.8 (Table 5.2-6). It appears that the higher concentrations at RM 10-11 are associated with the western nearshore area, whereas concentrations at RM 11-11.8 are associated with the eastern nearshore area (Maps 5.2-2l and m).

Overall, 6 samples had reported total PCB concentrations greater than 10,000 µg/kg. These were located in the eastern nearshore zone from RM 3-4, Swan Island lagoon, and the western nearshore zone from RM 8-9 (Tables 5.2-9 and 5.2-10). An additional 40 samples had reported concentrations between 1,000 and 10,000 µg/kg, all were located within the areas described above. Total PCB concentrations in subsurface sediment greater than 1,000 µg/kg account for five percent of the detected results, 34 percent (319 samples) were between 100 and 1,000 µg/kg, 50 percent were between 10 and 100 µg/kg, nine percent (88 samples) were between 1 and 10 µg/kg, and two percent (20 samples) had reported concentrations less than 1 µg/kg.

Downstream Reach (RM 0 to 1.9)

Total PCBs were reported in 13 of 26 subsurface sediment samples within the Downstream reach. Concentrations reported ranged from 5 µg/kg to 250 µg/kg (Table 5.2-20). Three samples had reported concentrations between 100 and 1,000 µg/kg, 62 percent (8 samples) had reported at concentrations between 10 and 100 µg/kg, and two samples had reported concentrations between 1 and 10 µg/kg. The mean total PCB concentration in this reach is 67 µg/kg (Tables 5.2-21 and 5.2-22).

~~5.13.76.4~~5.2.2.4 Total PCB Surface and Subsurface Sediment Relationships

~~Surface and subsurface sediment~~ The relationship~~s~~ between surface ~~-~~and subsurface sediment total PCB ~~concentratons~~concentrations were examined by ~~calculating ratios of~~

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~~mean total PCB concentrations (i.e., surface/subsurface) for the Study Area; for the east, middle, and west sides of the Study Area; for Multnomah Channel; and for Swan Island Lagoon. Ratios compared all surface and all subsurface sample intervals and excluded non-detected data. The magnitude of surface and subsurface mean total PCB concentrations were then plotted in a histogram to illustrate general trends in surface and subsurface chemical distributions. Statistical summaries for river mile reaches are provided in Table 5.1-3.~~ comparing surface and subsurface concentrations by reach, and also by subareas within the Study Area.

There are insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean surface sediment concentration in this reach is 4.48 µg/kg. Subsurface samples were non-detect for total PCBs, with a reporting limit of 11 µg/kg.

Within the downtown reach, Total PCB concentrations were higher in surface sediment than in subsurface sediment. Mean concentrations are 612 and 92 µg/kg in surface and subsurface sediment, respectively. Median concentrations are 45 µg/kg and 41 µg/kg in surface and subsurface sediments, respectively.

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Total PCB concentrations ~~were~~ are generally ~~higher~~ greater in subsurface sediments than in surface sediments within the Study Area ~~as a whole~~. The mean surface sediment concentration in the Study Area is 220 µg/kg and the mean subsurface sediment concentration is 351 µg/kg (Tables 5.2-1 and 5.2-2)~~(left side of Figure 5.1-33),~~[15] ~~with localized exceptions~~. Median total PCB concentrations in surface and subsurface sediment are, respectively, 26.9 µg/kg and 70 µg/kg. Mean concentrations are greater in the nearshore areas than in the navigation channel. PCB concentrations are greater in the eastern nearshore zone than the western nearshore zone, and are generally greater in the subsurface sediment than in surface sediment (Figure 5.2-3).

Subsurface sediment concentrations are greater than surface sediment In the eastern nearshore zone in all river miles zones except from RM 1.9-3, RM 6-7, RM 10-11, and RM 11-11.8. In the western nearshore zone, subsurface sediment concentrations are greater than in surface sediment in all river miles except RM 8-9. The subsurface sediment concentrations in the navigation channel are generally greater than the surface sediment concentrations, except from RM 11-11.8.

~~Where mean surface sediment total PCB concentrations are greater than mean subsurface concentrations the magnitude of difference is generally low (less than twice the mean~~

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~~[15] Note that the magnitude of mean surface/mean subsurface concentration ratios above "0" in Figure 5.1-33 indicate higher mean surface sediment concentrations while those below "0" reflect higher mean subsurface sediment concentrations. In situations where only surface samples were analyzed (i.e., RM 2-3 west bank, and RM 10-11 west bank), a ratio could not be calculated and is indicated by an asterisk on the figure.~~

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subsurface concentration), with the exception of the navigation channel at RM 11 to 11.8. Higher surface sediment concentrations on the east side the navigation channel between RM 11 and 11.8 are also evident in the core plots (see Map 5.1-2m), indicating a probable ongoing source.

5.13.76.5 Patterns and Trends of PCBs in Sediment

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This subsection includes a general description of the distribution of PCB homologs and Aroclors in sediment to provide information that may be used to infer the presence of different sources and PCB transport within the Study Area. Aroclor distributions are compared to homolog distributions to evaluate the Aroclor identifications made by the laboratories.

PCB homologs are congener groups based on chlorination level (i.e., the number of chlorine atoms [1–10] bonded to the biphenyl molecule). All of the PCB congeners within each homolog group are isomers. Homolog groups are identified as monochlorobiphenyl (one chlorine atom [$C_{12}H_9C_l$]; monoCB) through decachlorobiphenyl (10 chlorine atoms [$C_{12}Cl_{10}$]; decaCB). Examples of the PCB congener content of Aroclors has been reported by several authors (e.g., Erickson 1997, Frame et al. 1996) and was used to present the PCB homolog content of Aroclors in Figure 5.1-34. Identification of PCB Aroclors at the analytical laboratory can be subjective if the PCB pattern in the sample does not closely reflect the Aroclor standards. This is frequently the case in environmental samples as a result of fate and transport processes, the presence of more than one Aroclor in a sample, and chromatographic interference. Differing sorption, solution, and volatilization rates for different congeners and degradation processes can lead to weathering of Aroclors in the natural environment. Varying degrees of weathering were observed in the sediment samples, with some samples exhibiting what appeared to be weathered Aroclor patterns and other samples exhibiting Aroclor patterns that closely resembled Aroclor standards. Complex mixtures of two or more Aroclors were also observed in many sediment samples. Additional discussion about weathering and comparison of PCB congener and Aroclor totals is provided in Appendix D1.5.

PCB homolog group sums were calculated by summing the constituent congener concentrations, following the summation rules for the RI data.[16] PCB homolog and Aroclor compositions for samples within the Study Area are presented as bar charts in Figures 5.1-35 through 5.1-38. The bar charts show the percent composition of individual PCB homologs and Aroclors for each sample. In this data presentation, non-detected (U-qualified) homologs and Aroclors were assigned a value of zero; therefore, they do not appear on the bar charts. The figures are organized to show the east zone, navigation channel, and west zone (relative to the top of the navigation channel boundary). The dominant homolog (i.e., the homolog group detected at the highest concentration) at each sampling location is displayed on Maps 5.1-32 and 5.1-33, and the dominant Aroclor at each sampling location (i.e., the Aroclor detected at

[16] Calculated totals for each homolog are the sum of all detected constituent congeners. Non-detected congeners in a homolog group are assigned a value of zero. If all congeners in a homolog group were not detected, then the homolog total is assigned the highest detection limit among the constituent congeners and qualified with a U. For the bar chart presentations, U-qualified homologs and Aroclors are assigned a value of zero and, therefore, do not appear.

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the highest concentration) is shown on Maps 5.1-34 and 5.1-35. Subsurface homolog and Aroclor patterns are shown only for the depth interval with the highest PCB concentration at each location. The PCB composition at other depths may differ from that at the depth of maximum concentration.

Spatial variations in apparent PCB patterns are evident throughout the Study Area, and areas of high PCB concentrations often exhibit homolog patterns that appear distinct from surrounding areas of lower PCB concentrations. These variances in the relative abundances of the homolog groups potentially reflect the differences in the sources of the PCBs and the transport and weathering processes affecting the Aroclors. Overall, the tetrachlorobiphenyl (tetraCB), pentachlorobiphenyl (pentaCB), hexachlorobiphenyl (hexaCB), and heptachlorobiphenyl (heptaCB) homolog groups are predominant in the Study Area, with localized exceptions (Figures 5.1-35a–c and 5.1-36a–c). In the eastern nearshore zone, the overall chlorination level of PCBs in the surface and subsurface sediments tends to appear higher upriver in the Study Area and lower downstream. Between RM 6.7 and 11.3 in the eastern nearshore zone, the highest concentration samples are chiefly composed of hexaCBs and heptaCBs. The chlorination levels appear lower at several locations of higher PCB concentrations, from about RM 2 to 4 east, with a dominance of trichlorobiphenyls (triCBs), tetraCBs, and pentaCBs. Homolog patterns in areas of high PCB concentration appear to be more variable in the western nearshore zone.

The PCB homolog patterns in subsurface sediment appear generally similar to surface sediment patterns at the 37 locations where PCB congener data are available for both surface and subsurface sediment. However, PCB homolog patterns in subsurface sediment appear different from surface sediment at RM 2.8 (sample location LW3-G609/LW3-C609), RM 3.7 (sample location LW3-C093), and RM 8.4 (sample location LW3-C393) in the eastern nearshore zone; RM 10.1 (sample location LW3-G747) in the navigation channel; and at RM 5.1 (sample location LW3-G184), RM 7.7 (sample location LW3-G401), and RM 9.6 (sample location LW3-G738) in the western nearshore zone. As noted previously, patterns displayed by the stacked bar charts may or may not be statistically significant and indicative of different potential sources. Detailed forensic analyses would be required to distinguish significant patterns in the data and potential source contributions.

Aroclors 1248, 1254, and 1260 were identified throughout the Study Area (Figures 5.1-37a–h and 5.1-38a–d). Aroclor 1221 was identified locally in surface sediments, and Aroclors 1242 and 1268 were identified locally in both surface and subsurface sediments; however, these Aroclors were not widespread (Figures 5.1-37a–h and 5.1-38a–d). Within the Study Area, Aroclor 1016 was identified in one surface sediment sample, and Aroclors 1232 and 1262 were identified in one subsurface sediment sample each. Aroclor patterns in the subsurface sediments were also generally similar to the surface sediment patterns.

5.13.76.5.1 Comparison of PCB Homolog Patterns with Reported Aroclors

For areas with total PCB concentrations greater than 1,000 µg/kg and infrequently reported Aroclors, a comparison of identified Aroclors to the PCB homolog groups was made by comparing the Aroclor homolog profiles as presented in Figure 5.1-34. The PCB homolog

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~~data, where available, generally supported the Aroclor identifications of Aroclors 1242, 1248, 1254 and 1260, with two notable exceptions.~~

~~Near RM 8.8 (western nearshore zone) Aroclors 1242 and 1248 dominated the PCBs in surface and subsurface sediment, and concentrations greater than 1,000 µg/kg of Aroclor 1260 in surface sediment and Aroclor 1254 in subsurface sediment were also reported. Aroclors 1242 and 1248 are generally difficult to differentiate on a gas chromatogram and may be reported differently by different laboratories or analysts. The PCB homolog distribution in this area supports the identification of Aroclor 1242, although it does not definitively rule out the additional presence of Aroclor 1248 (Figures 5.1-37a–h and 5.1-38a–d). TriCBs were notably abundant in the sediment, often in a pattern that resembled Aroclor 1242 more than Aroclor 1248. The presence of dichlorobiphenyls (diCBs) further supports the identification of Aroclor 1242. Overall, the homolog patterns were very similar for the two samples in this area with the highest concentration (LW2-G453 and LW2-GBT028), even though the Aroclors identified in these samples were different. The reporting of two Aroclors in this area by the laboratories appears to reflect the difficulty of Aroclor identification rather than a difference in the PCBs present in the samples.~~

~~In samples with total PCB concentrations greater than 1,000 µg/kg at RM 2.1–2.5 (eastern nearshore zone), Aroclors 1248, 1254, and 1260 were identified in the surface and subsurface sediments in this area, and Aroclor 1242 was identified in five of the subsurface sediment samples. The PCB homolog distribution in this area was consistent with the identification of Aroclor 1248 as the predominant Aroclor in the surface sediments. However, for some subsurface samples (e.g. LW2-C015-B) the homolog pattern was not consistent with the reported Aroclors. Aroclors 1254 and 1260 were reported as dominant in these samples, but the homolog profiles for these samples resemble the profile for Aroclor 1242 or 1248, with a potential contribution of Aroclors 1254 or 1260. The lack of agreement between the homolog profiles and Aroclor identifications suggests the influence of weathering effects.~~

~~Aroclors not commonly reported in the Study Area (i.e., identified in fewer than 100 sediment samples or Aroclors other than 1242, 1248, 1254, and 1260) were also evaluated using PCB homolog data as described in the following paragraphs.~~

~~Aroclor 1221 was reported in surface sediment in the eastern nearshore zone and eastern edge of the navigation channel between RM 9.3 and 10 at concentrations up to 109 µg/kg (Station G472). However, the PCB homolog pattern is not consistent with Aroclor 1221 in the two samples from this area that were analyzed for PCB congeners. MonoCBs and diCBs are the dominant homologs in Aroclor 1221 (Erickson 1997; Figure 5.1-34), but tetra- through heptaCBs dominated the homolog profiles in this area. The same homolog profile was also present at adjacent location BT031, which was sampled at a later date and analyzed by a different lab, and for which Aroclor 1221 was not identified. Based on the PCB homolog patterns, and the fact that Aroclor 1221 is rarely reported in environmental samples, the identification of Aroclor 1221 in this area appears questionable.~~

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~~Aroclor 1221 was also identified in surface sediment at four isolated locations: in the eastern nearshore zone near RM 11, in the western edge of the navigation channel near RM 10.3, in the western nearshore zone at RM 7, and in the navigation channel near RM 8. PCB congeners were analyzed at all of these stations, and in all four cases, monoCBs and diCBs were not reported at sufficient levels to support the identification of Aroclor 1221. A focused review of Aroclor chromatograms confirmed the laboratory identifications, although some differences were noted in the PCB patterns in the samples relative to the standards. The differences in PCB patterns identified by the two methods may be the result of sample heterogeneity or another unidentified cause.~~

~~Aroclor 1268 was reported in surface and subsurface sediment in the eastern nearshore zone near RM 5.6 at concentrations up to 474 J µg/kg. PCB congener profiles generally confirm the presence of Aroclor 1268. Nonachlorobiphenyls (nonaCBs) and decaCBs are present in Aroclor 1268 (Figure 5.1-34) and were more abundant in both surface sediment locations and in one of the two subsurface sediment locations analyzed in this area than in areas without Aroclor 1268 detections.~~

~~Aroclor 1268 was also identified in isolated locations in several other areas. The Aroclor 1268 identifications were confirmed by the PCB homolog profile in surface sediments in the eastern nearshore zone at RM 3.7, off the mouth of the International Terminals Slip. PCB homolog profiles did not confirm the presence of Aroclor 1268 reported in surface and subsurface samples in the eastern nearshore zone near RM 4, the surface sediments in the eastern nearshore near RM 7.3, or in the subsurface sediments in the western nearshore zone near RM 7.4. Aroclor 1268 could not be evaluated at other locations because either no PCB homolog data were available, or Aroclor 1268 constituted a relatively small fraction of the Aroclor total.~~

~~Highly chlorinated PCBs were present at one location where Aroclor 1268 was not identified. At one subsurface location (C093-B) in the International Terminals Slip, nonaCBs and decaCB together accounted for approximately 25 percent of the PCB congener total, suggesting the presence of Aroclor 1268. A review of the Aroclor chromatogram for this sample confirmed the laboratories' Aroclor identifications. Again, the differences in PCB patterns identified by the two methods may be the result of sample heterogeneity or another unidentified cause.~~

~~Aroclors 1232 and 1016 were each identified in only one sample. Aroclor 1232 was identified in subsurface sediment at location PSY36C in the navigation channel near RM 8, and Aroclor 1016 was identified in surface sediment sample PP01M105 near the east bank of Swan Island Lagoon at approximately RM 8. The unique Aroclor constituted a small fraction of the total PCB Aroclors at both locations. PCB homolog data are not available at either location to corroborate the identifications; PCB homolog data at locations near these samples do not show evidence of Aroclors 1232 or 1016. The identity of these Aroclors is questionable.~~

~~Aroclor 1262 was also identified in only one sample, a subsurface sediment sample in the navigation channel at location LW3-C760 near RM 10.5. No PCB homolog data are available at or near this location and the Aroclor identification could not be confirmed.~~

Areas where subsurface sediment total PCB concentrations exceed 1,000 µg/kg

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generally align with the locations where surface sediment concentrations are greater than 1,000 µg/kg (Maps 5.2-2a-o and 5.2-3a-ff; Figures 5.2-1, 5.2-2 and 5.2-3). Exceptions occur in the eastern nearshore zone, PCB concentrations greater than 1,000 µg/kg in surface sediment are found from RM 6-7 and RM 5-6 in subsurface sediment. Although total PCB concentrations are greater than 1,000 µg/kg in subsurface sediment in the western nearshore area, total PCB concentrations in surface sediment approach but do not exceed 1,000 µg/kg.

The subsurface sediment concentrations in the downstream reach were greater than surface concentrations. The mean total PCB concentrations are 34 µg/kg and 67 µg/kg in surface and subsurface sediment, respectively. The median total PCB concentrations are 6.8 µg/kg and 46 µg/kg in surface and subsurface sediment, respectively.

~~5.13.7~~5.2.3 Total PCDD/Fs and TCDD TEQ in Sediment

Polychlorinated dibenzo-~~*p*~~-dioxins and polychlorinated dibenzofurans are evaluated as total polychlorinated dibenzo dioxins/furans (total PCDD/Fs). The summed total value for total PCDD/Fs represent the summed value of the measured homolog concentrations. The toxicity of dioxins and furans is determined by both the number and the position of the chlorine on the molecule, and appears to be a function of the ability to bind to specific cellular receptors. Because only those congeners having a chlorine in each of the 2, 3, 7, and 8 positions exhibit a toxicological response similar to 2,3,7,8-TCDD and other 2,3,7,8 substituted isomers appear to be slightly to substantially less potent, a toxicity equivalent factor is used to calculate a PCDD or PCDF toxicity equivalent concentration by multiplying the individual congener concentrations by its respective toxicity TEF. The TCDD TEQ represents the sum of the individual 2,3,7,8-TCDD equivalent concentrations.

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~~This section discusses the nature and extent of PCDD/Fs in surface and subsurface sediment samples collected within the Study Area. Also discussed is the distribution of TCDD TEQ concentrations and observed trends in the relative abundance of PCDD/F homologs in surface and subsurface samples. TCDD toxicity with respect to 2,3,7,8-TCDD was calculated from concentrations of PCDD/F congeners designated by the WHO as similar in mechanism of toxicity to 2,3,7,8-TCDD (Van den Berg et al. 2006). Each WHO-designated congener is assigned a specific TEF indicating its degree of toxicity compared to 2,3,7,8-TCDD, which is given a reference value of 1.~~

The distribution of total PCDD/Fs and TCDD TEQ concentrations at each surface sampling station throughout the Study Area is depicted ~~in~~ on Maps 5.2-6~~1-3~~ and 5.2-8~~1-5~~, respectively; concentrations with depth at subsurface stations are depicted in Maps 5.2-7~~1-4~~a–o~~m~~ and 5.1-~~9~~6a–o~~m~~, respectively. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-10a-l, including a key for interpreting the detailed subsurface chemistry maps.

The complete data set for total PCDD/Fs is plotted on scatter plots presented ~~in~~ on Figures 5.2-4~~51-7~~ ~~through~~ and 5.2-5~~61-10~~. Figures 5.2-7~~9~~ and 5.2-8~~10~~ present scatter

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plots of the TCDD TEQ data set for surface and subsurface sediment in the study area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigation channel, and western nearshore zones (Map 5.2-33).

Summary statistics for total PCDD/Fs and TCDD TEQ in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PCDD/Fs and TCDD TEQ data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally a histogram presenting the average surface and subsurface sediment values for total PCDD/Fs and TCDD TEQ by river mile and for the entire Study Area is presented in Figures 5.2-6~~7~~ and 5.2-9~~11~~.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented on Map 5.2-37 and 5.2-38. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment with the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect).

5.2.3.1 Total PCDD/Fs and TCDD TEQ Data Sets

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The ~~selection~~ number of sediment samples for PCDD/F analysis wa~~i~~s typically based on a ~~highly~~ biased approach at locations near known or suspected sources. As a result, there are relatively fewer data points for these analytes and the resulting TCDD TEQ data in the RI sediment database than for other chemicals (for example, the PCDD/F data set is approximately one-fifth the size of the PCBs and DDx data sets). This is particularly true in areas ~~away~~ not proximal ~~from~~ to suspected sources, such as the navigation channel.

The existing PCDD/F data are sufficient for RI purposes; however, as will be pointed out in this section and later in Section 10, the fewer number of data points for total PCDD/Fs in some areas limits the level of detail to which the extent of chemical distribution may be resolved, and introduces the need for caution in interpreting the surface to subsurface trends shown by the histograms (Figures 5.2-6~~7~~ and 5.2-9~~11~~~~Section 5.1.6.5~~), and in making conclusions regarding the spatial patterns of the composition of total PCDD/Fs and TCDD TEQ in sediment (Sections 5.2.3.2 through 5.2.3.5~~1.6.6~~). Total PCDD/Fs data for sediment within the Study Area are available for

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237 surface and 327 subsurface samples; there are 238 surface and 331 subsurface samples in the Study Area sediment TCDD TEQ data set.

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~~5.13.77.15~~5.2.3.2 Total PCDD/Fs in Surface Sediment

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Upriver Reach (RM 15.3 to 28.4)

Total PCDD/Fs were reported in 38 of 39 surface sediment samples within the Upriver reach (frequency of detection 97 percent). Concentrations range from 2.39 (0.00239 µg/kg) to 733 pg/g (Table 5.2-11). Concentrations between 100 and 1,000 pg/g were reported in 12 samples (Tables 5.2-13 and 5.2-14), between 10 and 100 pg/g in 17 samples, and between 1 and 10 pg/g in 9 samples. The mean total PCDD/Fs concentration in this reach is 90 pg/g, the median is 59 J pg/g.

Downtown Reach (RM 11.8 to 15.3)

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Total PCDD/Fs were detected in 62 of 67 surface sediment samples within the Downtown reach (frequency of detection of 93 percent). Detected concentrations ranging from 9.45 J pg/g to 15,400 J pg/g (Table 5.2-15a) with a mean of 1,130 pg/g. As shown on Map 5.2-37, the highest detected concentrations are located along the eastern shoreline.

Concentrations greater than 10,000 pg/g were reported in a single sample, between 1,000 and 10,000 pg/g in 17 samples, between 100 and 1,000 pg/g in 26 samples, between 10 and 100 µg/kg in 16 samples, and between 1 and 10 pg/g in 2 samples. This information is presented in Tables 5.2-17 and 5.2-18.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total PCDD/F data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total PCDD/Fs were detected in all 237~~16~~ surface sediment ~~samples in which this suite of chemicals was sampled~~analyzed. ~~Surface~~Reported concentrations ranged from 2.48 to 264,000 pg/g (Table 5.2~~1~~-1), the mean is 2,407 pg/g, and the median is 412 pg/g. ~~Ninety-five percent of the surface data was below 5,620 JV pg/g.~~ Detected concentrations exceeding 2,000 pg/g are indicated in red on Map 5.2-6. Total PCDD/F concentrations exceeding 1,000 pg/g are found in the eastern nearshore zone at RM 2-8, Swan Island Lagoon, and at RM 11. Mean concentrations (see Table 5.2-3) in these areas are 1,170 pg/g at RM 3-4; 1,640 pg/g at RM 4-5, 1,300 pg/g at RM 5-6, 3,440 pg/g at RM 6-7, 1,510 pg/g at RM 7-8, 3,030 pg/g in Swan Island Lagoon, and 1,510 pg/g at RM 11-11.8.

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Concentrations exceeding 1,000 pg/g are found in the western nearshore zone at RM 6-10 and from RM 4-6. Mean concentrations (see Table 5.2-7) in these locations are 726 pg/g at RM 4-5, 830 pg/g at RM 5-6; 1,730 pg/g for RM 6-7; 15,200 pg/g at RM 7-8; 1,500 pg/g at RM 8-9; and 1,690 pg/g at RM 9-10. The highest surface sediment concentration (264,000 pg/g) in the data set was detected between RM 7-8.

The highest total PCDD/F concentrations in the navigation channel zone are located at RM 6-7 and from RM 11-11.8. It appears that these concentrations are associated with higher concentrations found in the eastern nearshore zone (Map 5.2-6) rather reflecting conditions throughout the entire navigation channel. The maximum detected concentrations at these locations are 2,260 pg/g at RM 6-7, and 2,020 pg/g at RM 11-11.8. Mean concentrations are 779 pg/g at RM 6-7 and 810 pg/g at RM 11-11.8 (Table 5.2-5).

Total PCDD/F concentrations greater than 10,000 pg/g were detected in seven samples (Tables 5.2-9 and 5.2-10), 27 detected values are between 1,000 and 10,000 pg/g. Overall, concentrations greater than 1,000 pg/g account for 30 percent of the detected results (Map 5.2-6), 56 percent (133 samples) were between 100 and 1,000 pg/g, 13 percent (31 samples) were between 10 and 100 pg/g, and 1 percent (three samples) were detected at concentrations between 1 and 10 pg/g.

Total PCDD/F ~~The data show~~ concentrations greater than 2,000 pg/g (indicated in red on Map 5.2-6~~1 3~~) ~~total PCDD/Fs~~ were found at several locations along the eastern and western nearshore zones. Limited surface PCDD/F data are available ~~for~~ in the navigation channel, and spatial resolution is somewhat limited. However, of the channel samples that were analyzed, most concentrations were less than 500 pg/g~~,~~ (except as noted above~~,~~) and a pattern is evident of relatively high concentrations in nearshore areas compared with ~~markedly~~ lower ~~levels~~ concentrations in the adjacent channel areas.

Downstream Reach (RM 0 to 1.9)

Total PCDD/Fs were detected in all 21 samples within the Downstream reach. Concentrations reported ranged from 1.56 J pg/g to 1,780 J pg/g, with a mean concentration of 232 pg/g (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are only 3 data points Concentrations greater than 1,000 pg/g were reported in 3 samples, 38 percent (eight samples) of the reported concentrations were between 100 and 1,000 pg/g, 52 percent (11 samples) were between 1 and 10 pg/g.

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~~5.13.77.2~~5.2.3.3 Total PCDD/Fs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PCDD/Fs were detected in all three subsurface sediment samples in the Upriver reach, reported concentrations ranged from 3.59 pg/g to 1,090 pg/g (Table 5.2-12) with mean concentration of 816 pg/g. One sample had a reported concentration between

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1,000 and 10,000 pg/g, the other two results were between 100 and 1,000 pg/g (Tables 5.2-13 and 5.2-14).

Downtown Reach (RM 11.8 to 15.3)

Total PCDD/Fs were detected in 39 of 44 subsurface sediment samples and samples within the Downtown reach (detection frequency of 89 percent), with detected concentrations ranging from 4.74 pg/g to 4,590 J pg/g (Table 5.2-15a) and a mean concentration of 1,090 pg/g. Overall, concentrations between 1,000 and 10,000 pg/g were reported in 17 samples, 11 were between 100 and 1,000 pg/g, eight were between 10 and 100 µg/kg, and three were between 1 and 10 pg/g. There were no detected results less than 1 pg/g (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total PCDD/Fs data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total PCDD/Fs were detected in 325 of 327 subsurface sediment samples within the Study Area (frequency of detection 99 percent). Reported concentrations ranged from 0.0578 J pg/g to 425,000 J pg/g, with a mean concentration of 9,052 pg/g (Table 5.2-2). The distribution of reported concentrations is presented on Figure 5.2-5~~6~~ and Maps 5.2-4a-o~~).~~

~~Of the 241 subsurface samples analyzed, total PCDD/Fs were detected in all but one of the samples. Concentrations ranged from 0.0578 J pg/g to 218,000 pg/g (Table 5.1-2).~~

Total PCDD/F concentrations in subsurface sediment greater than 10,000 pg/g were found in the eastern nearshore zone from RM 6-7, in Swan Island Lagoon, and from RM 11-11.8 (Figure 5.2-5~~6~~). Concentrations greater than 1,000 pg/g in subsurface sediment are prevalent throughout the site, most frequently in the eastern nearshore zone from RM 2 through 8 and RM 11-11.8. Mean concentrations (see Table 5.2-4) in the eastern nearshore zone are 446 pg/g at RM 1.9-3; 638 pg/g at RM 3-4; 1,340 pg/g at RM 4-5; 561 at RM 5-6; 1,650 pg/g at RM 6-7; 19,500 pg/g at RM 7-8; 981 pg/g in Swan Island Lagoon; and 1,510 pg/g at RM 11-11.8.

Total PCDD/F concentrations exceed 10,000 pg/g between RM 6 and 8 in the western nearshore zone that (Figure 5.2-5~~6~~). Reported concentrations greater than 1,000 pg/g are ~~in subsurface sediment~~located from RM 4 through 11. The highest reported concentration of 425,000 J pg/g was found in core sample C455 (30–152 cm bml) RM 8.8 (Table 5.2-6). Mean concentrations in subsurface sediment in the western

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nearshore zone are 287 pg/g at RM 4-5, 33 pg/g at RM 5-6, 375 pg/g at RM 6-7, 2,270 at RM 7-8, 19,400 pg/g at RM 8-9, and 269 pg/g at RM 9-10.

Limited subsurface sediment data are available for the navigation channel, most reported concentrations were less than 100 pg/g. The highest concentrations in the subsurface samples are generally found in the same areas where concentrations greater than 1,000 pg/g were reported in surface samples (Maps 5.2-7a–o). Reported concentration greater than 1,000 were found from RM 6-7 and RM 11-11.8, and appear to be related to contamination found in the eastern nearshore zone.

Total PCDD/F concentrations greater than 10,000 pg/g were reported in 26 samples, 71 were between 1,000 and 10,000 pg/g (Tables 5.2-9 and 5.2-10), and overall 30 percent of the reported concentrations were greater than 1,000 pg/g. Reported concentrations between 100 and 1,000 pg/g comprise 32 percent (103 samples) of the detections, 23 percent (74 samples) were between 10 and 100 pg/g, 10 percent (31 samples) were between 1 and 10 pg/g, and 6 percent (20 samples) were less than 1 pg/g.

Downstream Reach (RM 0 to 1.9)

Total PCDD/Fs were detected in 17 of 17 samples analyzed within the Downstream reach. Reported concentrations ranged from 0.093 pg/g to 967 pg/g, the mean concentration is 145 pg/g (Table 5.2-20). Overall, concentrations greater than 100 pg/g account for 29 percent (5 samples) of the detected results, 41 percent (7 samples) were between 10 and 100 pg/g, 12 percent (2 samples) were between 1 and 10 pg/g, and 18 percent (3 samples) were detected at concentrations less than 1 pg/g (Tables 5.2-21 and 5.2-22).

5.2.3.4 TCDD TEQ in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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TCDD TEQ were calculated for 48 of 49 surface sediment samples within the Upriver reach. Calculated concentrations range from 0.00684 J pg/g to 2.99 pg/g (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there are Three results are between 1 and 10 pg/g, the majority (42 samples; 88 percent) are less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.3 pg/g.

Downtown Reach (RM 11.8 to 15.3)

TCDD TEQ were calculated 63 of 67 surface sediment samples within the Downtown reach, with concentrations ranging from 0.011 J pg/g to 19 J pg/g with a mean of 2.6 pg/g (Table 5.2-15a). TCDD TEQ concentrations in surface sediment in the Downtown reach are shown in Map 5.2-38. Two results are between 10 and 100 pg/g, 35 detected (56 percent) are between 1 and 10 pg/g, and 26 (41 percent), are less than 1 pg/g (Tables 5.2-17 and 5.2-18).

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In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the TCDD TEQ data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

TCDD TEQ were calculated for 238 surface sediment samples. Calculated concentrations range from 0.008 J to 14,100 J pg/g, with a mean of 68 pg/g (Table 5.2-1). These results are plotted on Figure 5.2-7~~9~~ and presented on Map 5.2-6, concentrations greater than 10 pg/g are indicated in red.

Total TCDD TEQ greater than 10 pg/g are present in the eastern nearshore from RM 6 through 8, in Swan Island Lagoon, and RM 11-11.8. Mean concentrations (see Table 5.2-3) in these areas are 16 pg/g at RM 6-7, 12 pg/g for RM 7-8, 4.9 pg/g in Swan Island Lagoon, and 4.4 pg/g at RM 11-11.8.

Total TCDD TEQ concentrations greater than 10 pg/g in the western nearshore zone are present from RM 6 to 10. Mean concentrations (see Table 5.2-7) in these areas are 20 pg/g at RM 6-7, 79 pg/g at RM 7-8, 3.6 pg/g at RM 8-9, and 4.6 pg/g at RM 9-10. The highest calculated TEQ concentration in surface sediment of 14,100 pg/g in the data set is between RM 7 and 8. There were no calculated concentrations in the navigation channel zone greater 10 pg/g.

Only one sample has calculated TCDD TEQ greater than 10,000 pg/g, there are no results between 1,000 and 10,000 pg/g, 4 results (2 percent) are between 100 and 1,000 pg/g, 28 results (12 percent) are between 10 and 100 pg/g, 107 samples (45 percent) are between 1 and 10 pg/g, and 98 results (41 percent) are less than 1 pg/g (Tables 5.2-9 and 5.2-10).

~~A total of 217 surface samples were selected for analysis of WHO-designated PCDD/Fs, with a frequency of detection of 100 percent. The resulting calculated TCDD TEQs show a wide range of values, from 0.00803 J pg/g to 14,100 J pg/g in surface sediment (Table 5.1-1). Ninety-five percent of the surface data were below 43.2 JV pg/g.~~

~~The data show that~~The spatial distribution ~~-~~TCDD TEQ values ~~vary spatially along the length of~~ in the Study Area ~~(~~is presented on Figure 5.2~~1~~ ~~-~~7~~9~~~~)~~. ~~In general, values~~Concentrations were higher in the western nearshore zone than in the eastern nearshore ~~and~~ or navigation channel ~~zones~~. The ~~most significant peak in the data~~highest reported results are present in the western nearshore ~~occurred~~ between ~~approximately~~ RM 6.8 and 7.3, where ~~data points are relatively dense~~the sample density if greater in comparison to the rest of the Study Area.

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Limited data for ~~WHO-designated PCDD/Fs~~TCDD TEQ are available for sediments in the navigation channel (Map 5.~~2~~1-~~8~~5). TCDD TEQ surface values within the channel were relatively low, with the exception of two samples with relatively ~~elevated~~ high concentrations along the eastern edge of the navigation channel between RM 6.6 and 6.7.

Downstream Reach (~~RM~~ RM 0 to 1.9)

TCDD TEQ were analyzed and detected in all 21 samples within the Downstream reach, with concentrations ranging from 0.0051 J pg/g to 2.6 J pg/g (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are only 2 data points with concentrations ranging between 1 and 10 pg/g. The majority of the data set (19 samples; 90 percent) were detected at concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.4 pg/g.

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~~5.13.77.3~~5.2.3.5 TCDD TEQ in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

TCDD TEQ were calculated in 3 subsurface sediment samples within the Upriver reach, concentrations range from 0.66 pg/g to 2.63 pg/g (Table 5.2-12). One result is between 1 and 10 pg/g, the remaining two results are less than 1 pg/g, with a mean concentration of 2 pg/g (Tables 5.2-13 and 5.2-14).

Downtown Reach (RM 11.8 to 15.3)

TCDD TEQ were calculated for 41 of 44 subsurface sediment samples within the Downtown reach. Calculated concentrations range from 0.0023 J pg/g to 13 pg/g (Table 5.2-15a), with a mean of 2.7 pg/g. There is a single result between 10 and 100 pg/g, 24 samples (59 percent) are between 1 and 10 pg/g, 16 samples (39 percent) are less than 1 pg/g (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. None of the TCDD TEQ data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

TCDD TEQ calculated for 238 of 331 subsurface sediment samples within the Study Area. Calculated concentrations range from 0.0003 J to 24,400 J pg/g, with a mean of 433 pg/g (Table 5.2-2). The distribution of TCDD TEQ concentrations in subsurface sediment in the Study Area is shown on Figure 5.2-~~8~~10, concentrations greater than 10 pg/g are indicated in red on Maps 5.2-9a-o and 5.2-10a-l.

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Concentrations greater than 10 pg/g are present in the eastern nearshore zone from RM 6 through 8, and from RM 11 to 11.8. Mean concentrations (see Table 5.2-4) in these areas are 5.8 pg/g at RM 6-7, 38 pg/g at RM 7-8, and 7.7 pg/g at RM 11-11.8.

Concentrations greater than 10 pg/g are present in the western nearshore zone from RM 4 through 9, with a prominent peak from RM 6.5 to 7.5. Mean concentrations (see Table 5.2-8) in these areas are 5.3 pg/g at RM 4-5, 2.5 pg/g at RM 5-6, 20 pg/g at RM 6 to 7, 73 pg/g at RM 7-8, and 37 pg/g at RM 8-9. The highest calculated TCDD TEQ concentration of 24,400 pg/g in surface sediment is located between RM 6.5 and 7.5. The maximum calculated subsurface TCDD TEQ value is at Station SD092 (0–90 cm vertically composited sample) at RM 7.2W (Map 5.2-9h).

Limited subsurface TCDD TEQ data are available from the navigation channel, and the majority of calculated results are less than 10 pg/g. Concentrations greater than 10 are only present in the navigation channel from RM 6-7 and appear to be related to the contamination in the western nearshore zone (Maps 5.2-9a-o and 5.2-10a-l). The highest concentrations in subsurface sediment are generally found at the same locations where TCDD TEQ are concentrations greater than 10 pg/g in surface sediment along the eastern and western nearshore zones (Maps 5.2-9a–o and 5.2-10a-l).

Tables 5.2-9 and 5.2-10 show that there are 3 data points greater than 10,000 pg/g. There are 14 detected values between 1,000 and 10,000 pg/g and 12 samples detected at concentrations between 100 and 1,000 pg/g. An additional 42 samples are detected at concentrations ranging between 10 and 100. Another 99 samples, or 32 percent, are detected at concentrations between 1 and 10 pg/g. Approximately half the detected data set (143 samples; 46 percent) is comprised of sample concentrations less than 1 pg/g.

The data show that TCDD TEQ values vary spatially along the length of the Study Area (Figure 5.2-8~~10~~). In general, values were higher in the western nearshore zone than in the eastern nearshore and navigation channel zones. The most significant peak in the data in the western nearshore occurred between approximately RM 6.8 and 7.3, where data points are relatively dense in comparison to the rest of the Study Area.

Limited data for TCDD TEQ are available for sediments in the navigation channel (Map 5.2-8). TCDD TEQ surface values within the channel were relatively low, with the exception of one sample with relatively elevated concentrations

~~WHO-designated PCDD/Fs were detected in approximately 93 percent of the 245 subsurface samples in which they were analyzed. The resulting calculated TEQs show a wide range of values, from an estimated 0.000262 J pg/g to an estimated 7,480 J pg/g in subsurface sediment (Table 5.1-2; Figure 5.1-10).~~

~~The maximum subsurface TCDD TEQ value was found at Station SD092 (0–90 cm vertically composited sample) at RM 7.2W (Map 5.1-6h).~~

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~~Within the navigation channel, TCDD TEQ values over 10 pg/g (indicated in red in Maps 5.1-6a-m) were calculated only at one subsurface station~~ near the western channel boundary at RM 6.6 (33.3 J pg/g in the interval from 132 to 243 cm bml at Station C314; Figure 5.2~~1-8~~10).

Downstream Reach (~~RM~~ RM 0 to 1.9)

TCDD TEQ were analyzed in 17 samples within the Downstream reach and detected in 16 samples (detection frequency of 94 percent), with concentrations ranging from 0.003 pg/g to 1.5 J pg/g (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there is only one data point with concentrations ranging between 1 and 10 pg/g. The majority of the data set (15 samples; 94 percent) were detected at concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.26 pg/g.

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~~5.13.77.4~~5.2.3.6 Total PCDD/F and TCDD TEQ Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination.

The surface total PCDD/Fs sediment concentrations in the downtown reach are slightly higher than the subsurface concentrations while the TCDD TEQ concentrations are approximately the same. The mean surface total PCDD/Fs concentration is 1,130 pg/g and the subsurface concentration is 1,090 pg/g. The surface TCDD TEQ concentration is 2.6 pg/g while the subsurface sediment concentration is 2.7 pg/g.

Total PCDD/Fs and TCDD TEQ concentrations are generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean total PCDD/Fs surface sediment concentration is 2,407 pg/g and the subsurface concentration is 9,052 pg/g; the mean total TCDD TEQ surface sediment concentration is 68 pg/g and the subsurface concentration is 434 pg/g. Most areas throughout the Study Area reach lack a strong or consistent vertical concentration gradient. This pattern may be due to the lack of samples and is supported by Maps 5.2-10a-l.

~~The magnitude of the mean surface and subsurface sediment concentrations for PCDD/Fs is shown on Figure 5.1-39. Summary statistics are presented in Table 5.1-4. The methods used to develop these presentations are described in Section 5.1.5.4. It should be noted that fewer data points are available for PCDD/Fs than for the other bounding chemical groups (PCBs, DDx, and PAHs). This relatively small sample size combined with the effect on the mean of one or two elevated values in a given subarea limits the interpretability of Figure 5.1-39; the actual mapped data patterns shown in Maps 5.1-4a-m are also discussed here.~~

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~~The surface/subsurface mean ratios show that total PCDD/F concentrations were slightly higher in surface sediments within the Study Area overall (left side of Figure 5.1-39), but the magnitude of the ratios are small, indicating that the average surface and subsurface concentrations were comparable across most of the Study Area. This pattern is supported by Maps 5.1-4a–m, which show that most areas lack strong or consistent vertical concentration gradients.~~ Some exceptions to this include the area under and just upstream of the Railroad Bridge at RM 6.9, where surface layers show higher concentrations than at depth (Map 5.2~~1~~-10~~4~~g) and the northwest corner of Willbridge Terminal where higher levels are evident at depth (Map 5.2~~1~~-10~~4~~h). This suggests a current source or sources at the former location and an historical source or sources at the latter. Elsewhere in the Study Area, significant changes in the level of PCDD/F inputs over time are generally not indicated by the data collected.

~~5.13.77.5 Patterns and Trends of PCDD/Fs in Sediment~~

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~~PCDD/F homolog compositions for samples within the Study Area are presented as bar charts in Figures 5.1-40a–c and 5.1-41a–c. The bar charts show the percent composition of the individual PCDD/F homologs for each sample. The figures are organized to show the east zone, navigation channel, and west zone (relative to the navigation channel boundary). Subsurface homolog patterns are shown only for the depth interval with the highest total PCDD/F concentration at each location. The PCDD/F composition at other depths may differ from that at the depth of maximum concentration.~~

~~OCDD is generally the dominant homolog (>50 percent of the total concentration) present in surface and subsurface sediments throughout the Study Area, with HpCDDs present to a significant but lesser degree. The other homolog groups generally constitute 20 percent or less of the total concentration. Exceptions where PCDD/F homolog distributions appear to vary significantly (possibly reflecting isolated areas of differing sources or weathering patterns) are clustered throughout the Study Area, with the largest clusters occurring along the western nearshore area around RM 6.8 and near RM 7.4, where data points are relatively dense in comparison to the rest of the Study Area.~~

~~The apparent variations in PCDD/F homolog compositions do not always reflect variations in total PCDD/F concentrations. Near RM 6.7E and from RM 6.8 to 7.4W, samples with high total PCDD/F concentrations are marked by a high proportion of furans relative to other areas. However, in general, samples with high PCDD/F concentrations have homolog profiles that match the prevailing pattern of OCDD and HpCDD dominance. Also, the surface and subsurface homolog distributions did not appear to vary greatly for any given location.~~

~~Finally, and as noted previously, definitive statements about spatial patterns in PCDD/F composition cannot be made based on the stacked bar charts, particularly for PCDD/Fs,~~

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~~which were analyzed based on a highly biased sampling design; this was not a primary goal of the RI sampling program. Detailed forensic analyses would be required to determine the existence of statistically significant patterns in the data.~~ The surface total PCDD/Fs sediment concentrations in the downstream reach are slightly higher than the subsurface concentrations while the TCDD TEQ concentrations are approximately the same. The mean surface total PCDD/Fs concentration is 232 pg/g and the subsurface concentration is 67 pg/g. The surface TCDD TEQ concentration is 0.4 pg/g while the subsurface sediment concentration is 0.3 pg/g.

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~~5.13.7~~5.2.4 ~~Total~~ DDx in Sediment

DDx represents the sum of the 2,4'- and 4,4'- isomers of DDD, DDE, and DDT. The distribution of DDx concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-11; concentrations with depth at subsurface stations are depicted on Maps 5.2-12a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-13a-gg, including a key for interpreting the detailed subsurface chemistry maps.

Figures 5.2-10~~3~~ and 5.2-11~~4~~ present scatter plots of the DDx data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for total DDx in the surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigational channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total DDx data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-12~~5~~.

Data for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, surface sediment sample locations within the Downtown reach are presented in Map 5.2-39. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-

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15 and 5.2-6; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). ~~Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-16.~~

The individual total DDT, DDD, and DDE concentrations (totals of the 2,4'- and 4,4'-isomers) are depicted in similar maps, tables and figures as total DDx in Appendix D1.

~~The distribution of concentrations of total DDx and its constituent compounds DDD, DDT, DDE in the Study Area sediment is summarized in this section. Observed trends in DDx isomers in surface and subsurface samples are also discussed. Frequencies of detection of total DDx were approximately 89 percent for surface samples and 81 percent for subsurface samples.~~

~~The distribution of total DDx concentrations at each surface sampling station throughout the Study Area is depicted in Map 5.1-7; concentrations with depth at subsurface stations are depicted in Maps 5.1-8a–m. The complete data set is plotted on scatter plots presented in Figures 5.1-11 and 5.1-12. The individual total DDT, DDD, and DDE concentrations (totals of the 2,4'- and 4,4'- isomers) are depicted in Maps D1.1-3 through D1.1-8 in Appendix D1.1.~~

~~Some of the results of the component isomers that were summed in the total DDx concentrations were N-qualified (Section 2.1.3.2). Additionally, some of the DDx isomer data are uncertain and potentially biased high because of the analytical interference from the presence of PCB congeners in the sample. The N-qualifier indicates that the quantity is estimated because there is only presumptive evidence that the chemical compound exists. When an individual isomer result is N-qualified, the N-qualifier is carried forward to the reported summed total. For individual isomers, the percentages of N-qualified sediment data range from zero (2,4'-DDE) to approximately 30 percent (2,4'-DDD) of both the surface and subsurface data. N-qualified total DDx concentrations range from 0.051 NJ µg/kg to 84,900 NJ µg/kg µg/kg in surface sediment and from 0.054 NJ µg/kg to 51,800 NJ µg/kg µg/kg in subsurface sediment.~~

~~5.13.7~~9.45.2.4.1 ~~Total~~ DDx in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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DDx was reported in 56 of 81 surface sediment samples within the Upriver reach (frequency of detection 69 percent). Concentrations reported range from 0.09J to 15J µg/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there is one result was reported at a concentration greater than 10 µg/kg, 73 were between 1 and 10 µg/kg, 14 samples (25 percent) were reported at a concentration less than 1 µg/kg. The mean concentration in this reach is 2 µg/kg.

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Downtown Reach (RM 11.8 to 15.3)

Total DDx was reported in 130 of 149 surface sediment samples within the Downtown reach (frequency of detection 87 percent). Reported concentrations range from 0.05J to 73J µg/kg (Table 5.2-15a), with a mean concentration of 6.6 µg/kg. The spatial distribution of DDx in surface sediment is presented on Map 5.2-39.

DDx concentrations between 10 and 100 µg/kg were reported in 25 samples, 76 results (58 percent) were between 1 and 10 µg/kg, and 29 samples were reported at concentrations less than 1 µg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total DDx data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

DDx was reported in 1,130 of ~~The results of the~~ 1,2~~10~~49 surface sediment samples within the Study Area (frequency of detection 90 percent). Concentrations reported range from ~~that were analyzed for both the 2,4'- and 4,4'- isomers of the DDx compounds are depicted on Map 5.1-7. Detected concentrations ranged from an estimated~~ 0.051-NJ ~~µg/kg~~ to ~~an estimated~~ 84,900 ~~A~~ µg/kg ~~in surface sediment~~ (Table 5.2~~1~~-1~~; Figure 5.1-11~~). ~~Ninety-five percent of the samples were less than 470 JV µg/kg.~~ The spatial distribution of DDX concentrations in surface sediment is presented on Figure 5.2-10~~4~~ and Map 5.2-11.

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~~Areas of total DDx~~, concentrations greater than 100 µg/kg ~~occurred~~ are observed at several locations ~~scattered~~ along the nearshore zones and channel margins ~~(Figure 5.2-13~~41~~)~~.

DDx concentrations greater than 100 µg/kg Areas are present in the eastern nearshore zone where at Swan Island Lagoon and RM 11E-11.8E (Map 5.2-11). Mean concentrations in these areas are 16 µg/kg in Swan Island Lagoon and 42 µg/kg at RM 11E-11.8E (Table 5.2-3).

DDx concentrations greater than 100 µg/kg are present in the western nearshore zone from RM 3W through RM 9W. The most prominent area~~s of total DDx concentrations greater than 100 µg/kg µg/kg occurred along the western shoreline~~ are between ~~RM~~ RM 6.3W and 7.5W, where~~. C~~ concentrations ~~above~~ greater than 10,000 µg/kg ~~(shown in red on Map 5.2-11-17)~~ were found at Station OSS002 ~~only in surface sediment~~ near ~~the western shore at RM~~ RM 7.2E (Map 5.2-11)~~5~~. ~~The maximum concentration was found at Station OSS002 in this vicinity. Another prominent peak is located~~ Upstream ~~along~~ DDx was reported at a concentration greater than 1,000 µg/kg in a single sample

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~~the western shoreline~~ at RM 8.8W~~, DDx was detected in a single sample at a concentration greater than 1,000 µg/kg~~. Mean DDx concentrations in these areas in the are 27 µg/kg at RM 3W-4W, 23 µg/kg at RM 4W-5W, 36 µg/kg at RM 5W-6W, 190 µg/kg at RM 6W-7W, 2,720 µg/kg at RM 7W-8W, and 123 µg/kg at RM 8W to 9W (Table 5.2-7).

~~With the exception of four samples,~~Within ~~samples collected within~~ the navigation channel, DDx ~~were less than 100 µg/kg. Concentrations~~ concentrations greater than 100 µg/kg were reported in four samples ~~were located~~ from three areas ~~at~~ RM 5.6 (maximum of 148 µg/kg), RM 6.5 (maximum of 274J µg/kg), and RM 11.3 (~~Figure 5.1-11~~maximum of 140 µg/kg). These areas are collocated with contamination present in the adjacent nearshore zones. Mean concentrations in these areas are 13 µg/kg at RM 5-6, 29 µg/kg at RM 6-7, and 25 µg/kg at RM 11-11.8 (Figure 5.2-10~~4~~).

~~The DDD, DDE, and DDT components show generally similar patterns of distribution, though relative concentrations vary (Maps D1.1-3, D1.1-5, and D1.1-7)~~DDx concentrations greater than 10,000 µg/kg were reported in seven samples (located between RM 7.2W and 7.5W), 22 reported values were between 1,000 and 10,000 µg/kg (also located between RM 7.2W and 7.5W,with one result being at RM 8.8), 92 results were between 100 and 1,000 µg/kg, 327 results were between 10 and 100 µg/kg, 636 results were between 1 and 10 µg/kg, and 46 results (four percent) were reported at a concentration less than 1 µg/kg (Tables 5.2-9 and 5.2-10). In all, DDx concentrations greater than 100 µg/kg account for 11 percent of the reported results in surface sediment (Map 5.2-11).

Downstream Reach (RM 0 to 1.9)

DDx was reported in 22 of 25 surface sediment samples within the Downstream reach (frequency of detection 88 percent). Concentrations reported range from 0.2 to 30J µg/kg (Table 5.2-19). DDx was reported at concentrations greater than 10 µg/kg in three samples, 14 results (64 percent) were reported at concentrations between 1 and 10 µg/kg, and five results were reported at concentrations less than 1 µg/kg. The mean DDx concentration in this reach is 5.2 µg/kg (Tables 5.2-21 and 5.2-22).

~~5.13.79.5~~5.2.4.2 ~~Total~~ DDx in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Only three subsurface sediment samples were analyzed for DDx, all between RM 15.4 and 16. DDx was reported in all three samples at concentrations from 1.0 to 9.7 µg/kg, with a mean of 5.8 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

DDx was reported in 64 of 94 subsurface sediment samples within the Downtown reach (frequency of detection 68 percent). Concentrations reported range from 0.05 to

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301 µg/kg (Table 5.2-16a), with a mean concentration of 16 µg/kg. One result was reported at a concentration greater than 100 µg/kg, 19 results were reported at concentrations between 10 and 100 µg/kg, 32 results were between 1 and 10 µg/kg, 11 results were reported at concentrations less than 1 µg/kg. No subsurface samples were collected in the vicinity of the Zidell facility (Tables 5.2-17 and 5.2-18).

Study Area Reach (RM 1.9 to 11.8)

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DDx was reported in 1,393 of ~~Of the~~ 1,678~~291~~ subsurface samples in the Study Area reach (~~samples analyzed for total DDx, detected~~ frequency of detection 83 percent). C~~c~~oncentrations reported rang~~ed~~ed from ~~an estimated~~ 0.058~~-~~J µg/kg to ~~an estimated~~ 3,643,000~~-A~~ µg/kg ~~in subsurface sediment~~ (Table 5.2~~1~~-2), the mean concentration is 11,200 µg/kg. The spatial distribution of DDx in the subsurface sediment is presented on Figure 5.2-11~~4~~ and Maps 5.2-12a-o and 5.2-13a-gg.

Areas in the eastern nearshore zone where DDx is reported at concentrations greater than 100 µg/kg total include a single results at RM 5E-6E and RM 6E-7E, Swan Island Lagoon, and RM 11E-11.8E. As observed with DDx concentrations in surface sediment, the extent of DDx greater than 100 µg/kg is confined to relatively small area at RM 11E, and more widely dispersed in Swan Island Lagoon (Maps 5.2-12a-o and 5.2-13a-gg). Mean concentrations in these areas in are 56 µg/kg at RM 5E-6E, 103 µg/kg at RM 6E-7E, 65 µg/kg in Swan Island Lagoon, and 464 µg/kg at RM 11E-11.8E (Figure 5.2-11~~4~~, Table 5.2-4).

~~Like the surface sediment,~~Areas in the western nearshore zone where DDx concentrations are greater than 100 µg/kg extend from RM 3W through RM 9W, concentrations greater than 10,000 µg/kg are present between RM 6.3W and 7.5W (Map 5.2-11). were also found near the RM 7.2.

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The maximum reported subsurface concentration was found in the interval 323 to 384 cm bml at Station WB-24 at RM 7.2E. DDx at concentrations greater than 1,000 µg/kg were reported from RM 7.2W to approximately RM 6.5W and RM 8.8W. Mean concentrations in these areas are 39 µg/kg at RM 3W-4W, 77 µg/kg at RM 4W-5W, 78 µg/kg at RM 5W to 6W; 322 µg/kg at RM 6W-7W, 36,900 µg/kg at RM 7W-8W, and 153 µg/kg at RM 8W-9W (Table 5.2-8).

Areas where DDx concentrations are greater than 100 µg/kg within the navigation channel are located from RM 3.2 to RM 5, RM 5.5 to RM 8.1, and RM 10.9 to RM 11.5 (Figure 5.2-11~~4~~), and correspond with contamination found in the adjacent nearshore zones. Mean concentrations in these areas are 18 µg/kg at RM 3-4, 74 µg/kg at RM 4-5, 19 µg/kg at RM 5-6, 229 µg/kg at RM 6-7, and 67 µg/kg at RM 7-8, and 11 µg/kg at RM 11-11.8.

DDx concentrations greater than 10,000 µg/kg were reported in 51 results, 83 results were between 1,000 and 10,000 µg/kg, 200 results (14 percent of the detected data)

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were between 100 and 1,000 µg/kg, 489 results (35 percent of the detected data) were between 10 and 100 µg/kg, 425 results (31 percent) were between 1 and 10 µg/kg, and 145 results (ten percent) were reported at a concentration less than 1 µg/kg (Tables 5.2-9 and 5.2-10). DDx concentrations greater than 100 µg/kg account for 24 percent of the detected results.

Downstream Reach (RM 0 to 1.9)

DDx was reported in 17 of 26 subsurface sediment samples within the Downstream reach (frequency of detection 65 percent). Concentrations reported range from 0.28NJ to 80 NJ µg/kg (Table 5.2-20). Reported DDx concentrations between 10 and 100 µg/kg were reported in 11 results, four were between 1 and 10 µg/kg, and two were reported at a concentration less than 1 µg/kg. The mean concentration in this reach is 19 µg/kg (Tables 5.2-21 and 5.2-22)

~~Of the samples collected within the navigation channel, the cores with concentrations greater than 100 µg/kg corresponded to areas of similar concentrations within the nearshore (Figure 5.1-12; Maps 5.1-8a–m).~~

~~5.1.7.7~~5.2.4.3 ~~Total~~ DDx Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean concentration in surface sediment in this reach is 2 µg/kg.

DDx concentrations in the downtown reach are lower in surface sediment than in subsurface sediment. Mean concentrations are 6.6 and 16 µg/kg in surface and subsurface sediment, respectively.

Within the Study Area, ~~The magnitude of total DDx mean surface and subsurface sediment concentrations is shown on Figure 5.1-42. Summary statistics are presented in Table 5.1-5. The methods used to develop these presentations are described in Section 5.1.5.4.~~

~~With the exception of one area (RM 11-11.8), t~~The mean ~~subsurface~~ DDx concentrations ~~of~~ in subsurface sediment ~~DDx are~~ is generally higher than ~~the~~ in surface sediment (Figure 5.2-12~~6~~). ~~concentrations throughout the Study Area (Figure 5.21-1642). The magnitude of the ratios are generally low, mostly around 5 or less; however, at RM 7-8 W, the mean subsurface levels greatly exceed the surface mean, indicating a large historical source or sources that has been markedly reduced over time. The only portions of the Study Area where surface sediment total DDx concentrations are higher than subsurface sediments are from RM 11–11.8E and in the navigation~~

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~~channel, possibly suggesting a current source or sources, but the magnitude of these ratios is relatively low. The surface/subsurface trends revealed by Figure 5.1-42 are supported by the data plotted in Maps 5.1-8a-m.~~

Areas where DDx concentrations are greater than 100 µg/kg in subsurface sediment generally align with the locations where surface sediment concentrations are greater than 100 µg/kg (Maps 5.2-11, 5.2-12a-o, and 5.2-13a-gg; Figures 5.2-10~~3~~, 5.2-11~~4~~ and 5.2-12~~5~~). Exceptions occur in the eastern nearshore zone from RM 3 to 5 and RM 7 to 8, the navigation channel from RM 7 to 11, and the western nearshore area from RM 9 to 10 where subsurface concentrations exceed 100 µg/kg, but surface sediment concentrations do not.

Within the downstream reach, DDx concentrations in subsurface sediment concentrations are greater than surface sediment concentrations. Mean concentrations are 5.2 and 19 µg/kg in surface and subsurface sediment, respectively.

~~5.13.80.0 Patterns and Trends of Total DDx in Sediment~~

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~~DDx patterns appeared to vary widely across the Study Area, as shown in Figures 5.1-43a-h (surface sediments) and 5.1-44a-d (subsurface sediments). Selected potential trends are summarized below. The bar charts in these figures include samples that may lack results for the 2,4' isomers of a DDx compound if these were not analyzed (see Appendix D1.6). The DDx patterns are incomplete for these samples. The discussion of subsurface sediment trends is based on the evaluation of DDx patterns only for the depth interval with the highest concentration at each location, presented in Figures 5.1-44a-d. The DDx composition at other depths may differ from that at the depth of maximum concentration.~~

~~As noted above, total DDx concentrations exceeded 10,000 µg/kg in one area located near RM 7 in the western nearshore zone. The main constituent of the surface sediments in this area was the 4,4' isomer of DDT (Figure 5.1-43g), while the 4,4' isomers of DDT and DDD were the main constituents of the subsurface sediments (Figure 5.1-44d). This pattern may indicate degradation of DDT to DDD in deep anoxic sediments.~~

~~The relative concentrations of the DDx isomers appear highly variable from station to station across the Study Area in both surface and subsurface sediment samples. However, a few general trends were observed:~~

- ~~The 4,4' isomer concentrations were greater than those for the 2,4' isomers of the DDx constituents overall. In some locations, the 2,4' isomers were more abundant than their 4,4' counterparts, particularly 2,4' DDD and, less frequently, 2,4' DDT. 2,4' DDE was rarely detected and was dominant only in samples with relatively low concentrations.~~

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- ~~Overall, samples with the highest concentrations tended to display a dominance of DDT and/or DDD isomers, particularly below RM 8.~~
- ~~There was a broad potential trend observed in the western nearshore DDx patterns. Both surface and subsurface sediment samples collected upstream of RM 8 generally had relatively low total DDx concentrations (typically between 10 and 100 µg/kg) and a large DDE component, whereas samples collected between RM 7.5 and 6.9 had relatively higher total DDx concentrations (generally higher than 100 µg/kg) and were dominated by DDT, and samples downstream of RM 6.9 had relatively lower total DDx concentrations (generally less than 100 µg/kg) and a larger apparent DDD component. These upstream/downstream trends were also evident in the navigation channel, which generally paralleled the western nearshore trends from RM 12 to about RM 4 (except where embayments such as Willbridge are crossed). In contrast, the eastern nearshore patterns were more like those of the western nearshore zone above RM 8.~~

~~5.13.8~~7~~5.2.5~~ Total PAHs in Sediment

Total PAHs is defined as the sum of the individual PAH compound concentrations. ~~The distribution and composition of total PAH concentrations in Study Area sediment are summarized in this section.~~ The distribution of total PAHs concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-14; concentrations with depth at subsurface stations are depicted on Maps 5.2-15a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-16a-gg.

Figures 5.2-13~~7~~ and 5.2-14~~8~~ present scatter plots of the total PAHs data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for total PAHs in the surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigational channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PAHs data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-15~~9~~.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the

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Downtown reach surface sediment samples are presented in Map 5.2-40. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-6; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect).

5.2.5.1 Total PAHs Data Set

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Frequencies of detection of PAH compounds were high, approximately 99 percent in surface samples and 95 percent in subsurface samples. The Study Area data set of total PAH concentrations includes 1,6610~~3~~ surface samples and 1,696~~545~~ subsurface samples. The Upriver data set includes 78 surface samples and 3 subsurface samples. The downtown data set includes 269 surface samples and 161 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.~~Frequencies of detection of PAH compounds were high, approximately 99 percent in surface samples and 95 percent in subsurface samples.~~

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~~Map 5.1-9 shows the distribution of total PAH concentrations at each surface sampling station throughout the Study Area; concentrations with depth at subsurface stations are depicted in Maps 5.1-10a–m. The complete data set is plotted on scatter plots presented in Figures 5.1-13 and 5.1-14.~~

~~5.13.87.2~~5.2.5.2 Total PAHs in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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Total PAHs were reported in 63 of 78 surface sediment samples within the Upriver reach (frequency of detection 81 percent). Concentrations reported range from 0.91J to 1,510 µg/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that only one result was reported at a concentration greater than 1,000 µg/kg, 17 (27 percent of the detected data set) were between 100 and 1,000 µg/kg, 39 results (62 percent) were between 10 and 100 µg/kg, 5 were between 1 and 10 µg/kg, and one result was reported at a concentration less than 1 µg/kg. The mean total PAHs concentration in this reach is 74 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

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Total PAHs were reported in 248 of 269 surface sediment samples within the Downtown reach (frequency of detection 92 percent). Concentrations reported range from 0.73 to 62,500 µg/kg (Table 5.2-15a), with a mean of 2,174 µg/kg. The spatial distribution of total PAHs in the Downtown reach is presented on Map 5.2-40, reported

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concentrations greater than 10,000 µg/kg were observed at RM 12.2W, 12.5W, between RM 13.5W and 14W, and at 12.3E.

Total PAHs were reported at a concentration greater than 10,000 µg/kg in 11 results, 55 were between 1,000 and 10,000 µg/kg, 121(49 percent) were between 100 and 1,000 µg/kg, 41 (17 percent) were between 10 and 100 µg/kg, 17 were between 1 and 10 µg/kg, and three results were reported at a concentration less than 1 µg/kg (Tables 5.2-17 and 5.2-18). Within this reach, 27 percent of the detected results were reported at a concentration greater than 1,000 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Total PAHs were analyzed in 112 surface sediment samples (frequency of detection 88 percent). Concentrations reported range from 0.0734 to 32,000 µg/kg, with a mean of 2,538 µg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), reported total PAHs concentrations in surface sediment range from 0.57J to 62,500 µg/kg, with a mean of 1,940 µg/kg.

Study Area Reach (RM 1.9 to 11.8)

Total PAHs were reported in 1,640 of 1,661 surface sediment samples within the Study Area (frequency of detection 99 percent). Concentrations reported range ~~of total PAHs in surface sediment varied widely,~~ from 3.3 J ~~µg/kg~~ to 7,260,000 µg/kg (Table 5.2~~1~~-1). ~~Ninety-five percent of the 1,603 surface samples were less than 66,600 JV µg/kg.~~

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The ~~data,~~distribution of reported concentrations varies throughout the Study Area, and is particularly heterogeneous above RM 6.5 where ~~samples are more abundant~~sample density is greater~~, showed variable concentrations throughout the Study Area~~ (Figure 5.2-13).

Areas where ~~Except for several areas of relatively higher concentrations,~~ total PAH ~~levels~~ concentrations are ~~were generally~~ less than 1,000 µg/kg are found in several locations within the Study Area ~~or less in channel and nearshore zones of the main stem of the river (i.e., outside Swan Island Lagoon). The~~, including the lower end of the Study Area from ~~RM~~ RM 1.9 to 3, the upper end of the Study Area from RM 10 to 11.8 (except 3 samples in the eastern nearshore zone), and in the eastern nearshore zone between RM 6 and 10. The only area in the Navigation Channel with reported concentrations greater than 1,000 µg/kg is from RM 5 to 7~~in the upper portion of the Study Area between RM 7 and 11.8~~ (Figure 5.2~~1~~-1~~3~~3~~7~~; Map 5.2~~1~~-1~~49~~).

~~Scattered areas of~~Reported concentrations greater than 1,000 µg/kg ~~were~~ are ~~found~~ located throughout the Study Area, areas where~~but the highest~~ concentrations ~~(>~~ greater than 2~~3~~0,000 µg/kg ~~; indicated in red on Map 5.1-9)~~ were ~~most commonly~~

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~~found~~encountered in the eastern nearshore zone from RM 4.2E to 4.8E ~~in the eastern nearshore zone~~ and in the western nearshore zone~~s~~ from RM 5.9W to 6.8W ~~between approximately RM 4 and 7.5~~ (Figure 5.2~~1~~-13~~7~~; Map 5.2-14~~3~~). The highest reported total PAH concentration in surface sediment of 7,260,000 µg/kg was reported in the western nearshore zone at RM 6.3W (Station G225).

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Total PAH concentrations ~~above~~ greater than 2~~3~~0,000 µg/kg were also found adjacent to the western nearshore zone in surface sediment in the navigation channel from RM 5.2 to 6.8 ~~adjacent to the RM 5.2- 6.8 reach~~.

Mean total PAH concentrations by river mile for areas in the eastern nearshore zone with reported concentrations greater than 1,000 µg/kg are 5,160 µg/kg at RM 1.9E-3E, 3,850 µg/kg at RM 3E-4E, 35,100 µg/kg at RM 4E-5E, 5,170 µg/kg at RM 5E-6E, 3,870 µg/kg at RM 6E-7E, 1,420 µg/kg at RM 7E-8E, 3,580 µg/kg in Swan Island Lagoon, 4,850 µg/kg at RM 10E-11E, and 3,640 µg/kg at RM 11E-11.8E (Table 5.2-3).

Mean concentrations by river mile for areas in the western nearshore zone with reported concentrations greater than 1,000 µg/kg are 4,740 µg/kg at RM 3W-4W, 7,940 µg/kg at RM 4W-5W, 17,300 µg/kg at RM 5W-6W, 192,000 µg/kg at RM 6W-7W, 3,490 µg/kg at RM 7W-8W, 2,280 µg/kg at RM 8W- 9W; and 2,510 µg/kg at RM 9W-10W (Table 5.2-7).

Mean total PAH concentrations by river mile in the navigation channel for areas where concentrations are greater than 1,000 µg/kg are 275,000 µg/kg at RM 5-6 and 58,600 µg/kg at RM 6-7 (Table 5.2-5).

Total PAH concentrations greater than 10,000 µg/kg were reported in 233 results, 636 were between 1,000 and 10,000 µg/kg, 661 were between 100 and 1,000 µg/kg, 104 were between 10 and 100 µg/kg, and six results were reported at concentrations ranging from 1 to 10 µg/kg (Tables 5.2-9 and 5.2-10). Fifty-five percent of the results within the Study Area were reported at concentrations greater than 1,000 µg/kg (Map 5.2-14).

Downstream Reach (RM 0 to 1.9)

Total PAHs were reported in 25 of 25 surface sediment samples within the Downstream reach. Concentrations reported range from 1.4J µg/kg to 18,000J µg/kg (Table 5.2-19). One result was reported at a concentration greater than 10,000 µg/kg, one was between 1,000 and 10,000 µg/kg, 16 were between 100 and 1,000 µg/kg, six were between 10 and 100 µg/kg, and one result was between 1 and 10 µg/kg (Tables 5.2-21 and 5.2-22). The mean total PAHs concentration in this reach is 1,120 µg/kg.

~~5.13.87.3~~5.2.5.3 Total PAHs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

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Total PAHs were reported in three of three samples collected between RM 15.4 and 16. Concentrations reported range from 253 µg/kg to 533 µg/kg, with a mean of 366 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PAHs were reported in 157 of 161 subsurface sediment samples within the Downtown reach (frequency of detection 98 percent). Concentrations reported range from 0.25J to 4,850,000 µg/kg (Table 5.2-16a), with a mean of 235,000 µg/kg. Total PAH concentrations greater than 10,000 µg/kg were reported in 30 results, 39 results were between 1,000 and 10,000 µg/kg, 52 results were between 100 and 1,000 µg/kg, 23 results were between 10 and 100 µg/kg, six were between 1 and 10 µg/kg, and seven results were reported at concentrations less than 1 µg/kg (Tables 5.2-17 and 5.2-18). Within this reach, reported concentrations than 1,000 µg/kg account for 44 percent of the detected results, with the highest concentrations observed in the western nearshore area at RM 12.2 (Figure 5.2-184).

Twelve of the subsurface samples were collected in the vicinity of the Zidell facility, reported concentrations ranged from 4.8 to 451 µg/kg. With these values excluded, the mean and median total PAH concentrations are 235,000 and 770 µg/kg, respectively.

Study Area Reach (RM 1.9 to 11.8)

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Total PAHs were reported in 1,643 of 1,715 subsurface samples (frequency of detection 96 percent). Concentrations reported range from 0.15J µg/kg to 53,300,000 µg/kg (Table 5.2-2).

~~Of the 1,545 subsurface samples analyzed for total PAHs, the concentration range varied widely, from 0.15 J µg/kg to 53,300,000 µg/kg in subsurface sediment (Table 5.1-2).~~

~~Similar to surface sediment, scattered areas of~~ Areas where total PAH concentrations exceeded ~~concentrations greater than 1,000 µg/kg in subsurface sediment were found throughout the Study Area, and concentrations greater than~~ 130,000 µg/kg were ~~most~~ observed ~~commonly found~~ in the eastern nearshore zone between RM 3.5E and 7.5E and in Swan Island Lagoon. Mean concentrations by river mile in these areas are 22,000 µg/kg at RM 3E-4E, 23,500 µg/kg at RM 4E-5E, 11,600 µg/kg at RM 5E-6E, 6,560 µg/kg for RM 6E-7E, 3,010 µg/kg at RM 7E-8E, and 3,400 µg/kg in Swan Island Lagoon (Table 5.2-4).

Locations in the western nearshore where total PAHs concentrations greater than 10,000 µg/kg are observed include ~~and western nearshore zones between approximately~~ RM 3W ~~and~~ to 7.5W and at RM 9.2W (Figure 5.2~~1~~-1~~484~~;, Maps 5.2~~1~~-1~~50~~a–0 and 5.2-16a-gg~~m~~). The highest concentrations in subsurface sediment are found between RM 6W and 6.5W, the highest reported value of 53,300,000 µg/kg was

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observed in this area at Station C302. Mean concentrations by river mile in these areas are 19,000 µg/kg at RM 3W-4W, 24,700 µg/kg at RM 4W-5W, 45,400 µg/kg at RM 5W-6W, 1,610,000 µg/kg at RM 6W-7W, 3,560 µg/kg at RM 7W-8W, and 19,200 µg/kg for RM 9W-10W (Table 5.2-8).

Total PAH concentrations ~~above~~ greater than ~~3~~10,000 ~~µg/kg~~ µg/kg were also ~~found~~ observed in subsurface sediment in the navigation channel from ~~RM~~ RM 4 to 6.5, adjacent to and downstream from the high concentration area in the western nearshore zone between RM 6 and 6.5. Mean concentration by river mile in this area are. 5,240 µg/kg at RM 4-5, 8,450 µg/kg at RM 5-6, and 453,000 µg/kg at RM 6-7 (Table 5.2-6).

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Within the Study Area, total PAH concentrations greater than 10,000 µg/kg were reported in 335 results, 563 were between 1,000 and 10,000 µg/kg, 484 were reported at concentrations between 100 and 1,000 µg/kg, 137 were detected at concentrations between 10 and 100 µg/kg, 87 were between 1 and 10 µg/kg, and 37 results were reported at concentrations less than 1 µg/kg. Concentrations greater than 1,000 µg/kg account 54 percent of the reported results within the Study Area (Tables 5.2-9 and 5.2-10)

Downstream Reach (RM 0 to 1.9)

Total PAHs were reported in all 26 subsurface sediment samples collected within the Downstream reach. Concentrations reported range from 0.49J to 23,000 µg/kg (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there is One result was reported at a concentration greater than 10,000 µg/kg, four were between 1,000 and 10,000 µg/kg, 10 were between 100 and 1,000 µg/kg, seven results were reported at concentrations between 10 and 100 µg/kg, two were between 1 and 10 µg/kg, and two results were reported at a concentration less than 1 µg/kg. Within the Study Area, reported concentrations greater than 1,000 µg/kg account for 19 percent of the reported results in subsurface sediment. The mean total PAH concentration in the Study Area is 1,340 µg/kg.

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~~5.13.87.4~~5.2.5.4 Total PAHs Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach.

There are insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean total PAH concentration in this reach is 107 µg/kg.

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Total PAH concentrations within the Downtown reach are greater in subsurface sediment relative to concentrations observed in surface sediment. Mean concentrations are 2,174 and 219,700 µg/kg in surface and subsurface sediment, respectively.

Within the Study Area, total PAH concentrations are generally greater in subsurface than in surface sediments. Mean concentrations in surface and subsurface sediments are 27,200 and 249,000 µg/kg (Tables 5.2-1 and 5.2-2). Localized areas where concentrations are greater in surface sediment are found from RM 1.9E to 3E, RM 4E to 5E, Swan Island Lagoon, and RM 10E to 11.8E within the eastern nearshore zone, except RM 8W to 9W in the western nearshore zone, and RM 5 to 6, RM 8 to 9, and RM 9 to 10 within the navigation channel.

~~The magnitude of mean total PAH surface/subsurface sediment concentrations is shown on Figure 5.1-45. Summary statistics are presented in Table 5.1-6. The methods used to develop these presentations are described in Section 5.1.5.4.~~

~~The surface/subsurface mean ratios show that total PAH concentrations were slightly higher in subsurface sediments within the Study Area as a whole (left side of Figure 5.1-45).~~

Areas with the highest reported total PAH concentrations in both surface and subsurface sediment generally align (Maps 5.2-15a-o and 5.2-16a-gg and Figures 5.2-13~~7~~, 5.2-14~~8~~, and 5.2-15~~9~~).

Within the downstream reach total PAH concentrations are greater subsurface than in surface sediment, Mean concentrations are 1,120 and 1,340 µg/kg in surface and subsurface sediment, respectively.

~~In areas where mean subsurface total PAH concentrations were greater than mean surface total PAH concentrations, the highest magnitude was at RM 6-7 in the navigation channel followed by RM 11-11.8 E. In areas where mean surface sediment total PAH concentrations were greater than subsurface concentrations the highest magnitude was at RM 5-6 in the navigation channel. Inspection of Map 5.1-10g indicates that the high subsurface mean at RM 6-7W is driven by some high PAH concentrations (>30,000 µg/kg) in core samples collected at the channel edge off of the Gasco early action area. The relatively high surface/subsurface mean ratio in the channel from RM 5-6 is driven by several high concentration (>30,000 µg/kg) surface-only samples in the channel.~~

~~5.13.87.6 Patterns and Trends of Total PAHs in Sediment~~

~~The distribution of detected PAHs at each location is presented in Figures 5.1-46a-j (surface sediment) and Figures 5.1-47a-f (subsurface sediment). In order to simplify the bar charts, PAHs were grouped according to the number of fused aromatic rings in~~

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the PAH. A list of individual PAHs included in the sum for each of these groups is provided in Table 5.1-7. Only PAHs analyzed for LWG samples are summed. Of these PAHs, two-ring PAHs include only naphthalenes (i.e., naphthalene and 2-methylnaphthalene). LPAHs include PAHs with two or three rings (green and yellow segments), and HPAHs include PAHs with four to six rings (purple, red, and blue segments). Only the depth interval that contained the highest total PAH concentration is shown in Figures 5.1-47a–f (i.e., the subsurface charts represent a variety of depths based on the interval of the maximum concentration) and evaluated below.

Surface sediments within the Study Area are generally dominated by HPAHs, primarily four-ring PAHs, with localized exceptions. Five-ring PAHs are the second most abundant HPAH, followed by six-ring PAHs. Three-ring PAHs are the principal LPAH in surface sediments, with two-ring PAHs generally being a minor component of the surface sediment PAH profile. Surface sediments from the western nearshore zone appeared to exhibit higher proportions of LPAHs than sediments from the eastern nearshore zone and the navigation channel, but follow the general trend of HPAH dominance. Some areas of high total PAH concentration have PAH profiles that appear to differ from the prevailing trend of HPAH dominance, the most notable between RM 6.2 and 6.9 in the western nearshore zone. In this area increased contributions from two and three-ring PAHs, and a corresponding reduced six-ring PAH abundance is also observed. Similar high PAH profiles are observed between RM 6.4 and 7.2 in the eastern nearshore zone and between RM 5.6 and 7.4 in the navigation channel.

Subsurface sediments appear to have greater contributions from two- and three-ring PAHs than the surface sediments, but generally exhibit similar PAH profiles to the surface sediments.

The proportions of individual PAH compounds varied throughout the Study Area, reflecting PAH contributions from multiple types of hydrocarbon sources, as well as weathering and degradation. Hydrocarbon source types include pyrogenic (e.g., tars and creosote), petrogenic (e.g., fresh oil), and a variety of combustion processes and natural biological production processes. PAHs characteristic of these source types include alkylated PAH compounds, which are especially useful in distinguishing between pyrogenic and petrogenic source types. Alkylated PAH data are available for selected sediment and clam tissue samples and are presented in the SCRA database and summary statistics in Appendix D; however, these data are not discussed in the RI report. Once again, detailed forensic analyses would be required to identify significant differences among the PAH patterns within the sediment data set and to distinguish contributions from potential source types.

5.13.87 Additional Indicator Chemicals in Sediment

This section discusses the occurrence and distribution of nine additional ICs in sediment within the Study Area. The narrative in this section is less comprehensive than the preceding sections, omitting the data set description, surface/subsurface relationships,

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~~patterns and trends, and referring instead to maps, tables, and figures to provide a general picture of the distribution of those chemicals. The nature and extent data for the remaining 21 sediment ICs listed in Table 5.0-2 are presented on all tables, maps, and figures in Appendix D.~~

~~5.13.87.13~~5.2.6 Bis(2-ethylhexyl)phthalate in Sediment

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The distribution of BEHP concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-17; concentrations with depth at subsurface stations are depicted on Maps 5.2-18a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-16~~21~~ and 5.2-17~~22~~ present scatter plots of the BEHP data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for BEHP in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present BEHP data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-18~~23~~.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-41. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect).

5.2.6.1 BEHP Data Set

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The Study Area data set of BEHP concentrations includes 1,513 surface and 1,591 subsurface samples, the Upriver data set includes 72 surface and 3 subsurface samples, the downtown data set includes 96 surface samples and 64 subsurface samples, and the

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downstream data set includes 21 surface and 17 subsurface samples. Because the reporting limit for several nondetect results were greater than the maximum reported values (Figures 5.2-16~~21~~ and 5.2-17~~22~~), thus, the majority of this discussion will focus on detected values.

5.2.6.2 BEHP in Surface Sediment

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Upriver Reach (RM 15.3 to 28.4)

BEHP was reported in 56 of 72 surface sediment samples and within the Upriver reach (frequency of detection 78 percent). Concentrations reported range from 4.2J to 2,100 µg/kg (Table 5.2-11). One result was reported at a concentration greater than 1,000 µg/kg, nine were between 100 to 1,000 µg/kg, 40 results were between 10 and 100 µg/kg, and six were between 1 and 10 µg/kg (Tables 5.2-13 and 5.2-14). The mean BEHP concentration in this reach is 94 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

BEHP was reported in 78 of 96 surface sediment samples within the Downtown reach (frequency of detection 81 percent). Concentrations reported range from 7.6J to 18,000 µg/kg (Table 5.2-15a), with a mean of 418 µg/kg. The spatial distribution of BEHP in surface sediment is presented on Map 5.2-41.

Within the Downtown reach, one result was reported at a concentration greater than 10,000 µg/kg, one result was between 1,000 and 10,000 µg/kg, 32 were between 100 and 1,000, 39 were between 10 and 100 µg/kg, and 5 results were reported at concentrations between 1 and 10 µg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the BEHP data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

BEHP was reported in 932 of 1,513 surface sediment samples within the Study Area (frequency of detection 62 percent). Concentrations reported range from 7J to 440,000J µg/kg (Table 5.2-1), with a mean of 1,050 µg/kg. The spatial distribution of BEHP in surface sediment is presented on Figure 5.2-16~~21~~.

Areas where BEHP concentrations are greater than 1,000 µg/kg were observed in the eastern nearshore zone between RM 3.8E and 4.1E and in the International Terminals Slip, Swan Island Lagoon, RM 7E and 8E and at RM 11.2E (Figure 5.2-16~~21~~, Map 5.2-17). ~~Concentrations of BEHP were ≤1,500 µg/kg in the majority of samples analyzed (Maps 5.1-11 and 5.1-12a–m, see frequency plot inset; Figures 5.1-15 and 5.1-16). Limited areas with concentrations greater than 1,500 µg/kg were found at several~~

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~~locations within the Study Area. Frequencies of detection were 61 percent for surface samples and 39 percent for subsurface samples. Ninety-five percent of the surface samples were below 2,230 JV µg/kg (Table 5.1-1).~~

~~Clusters of concentrations greater than 1,500 µg/kg occurred in the surface data set from the eastern nearshore, in Swan Island Lagoon, and between RM 3.8 and 4.1 in the International Terminals Slip and along the riverfront (Maps 5.1-11 and 5.1-12a-m).~~ The highest reported surface concentration in the Study Area of 440,000J µg/kg was found at Station G367 at the mouth of Swan Island Lagoon. Mean BEHP concentrations by river mile in these areas are 1,310 µg/kg at RM 3E-4E, 792 µg/kg at RM 4E-5E, 573 µg/kg at RM 7E-8E; 6,150 µg/kg in Swan Island Lagoon, and 204 µg/kg at RM 11E-11.8E (Table 5.2-3)

BEHP concentrations greater than 1,000 µg/kg were observed in the western nearshore zone from RM 6W through 10W, with a prominent peak at RM 8.8W (Figure 5.2-16~~21~~). Mean concentrations by river mile are 256 µg/kg at RM 6W-7W, 347 at RM 7W-8W, 745 µg/kg at RM 8W-9W, and 531 µg/kg at RM 9W-10W (Table 5.2-7).

The greatest concentrations observed in the navigation channel zone are located near RM 10, and appear to be associated with the eastern nearshore area (Map 5.2-17). Additional elevated concentrations are located at RM 5.2, Swan Island Lagoon, and RM 10.3 in the western nearshore area (Map 5.2-17). Mean concentrations in these areas are 203 µg/kg at RM 5-6, 679 µg/kg in Swan Island Lagoon, and 446 µg/kg at RM 10-11 (Table 5.2-5).

BEHP concentrations greater than 10,000 µg/kg were reported in nine results, 79 were between 1,000 and 10,000 µg/kg, 501 (54 percent of the detected results) were reported at concentrations between 100 and 1,000 µg/kg, 336 were between 10 to 100 µg/kg, and seven results were reported at concentrations between 1 and 10 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

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BEHP was reported in 10 of 21 surface sediment samples within the Downstream reach (frequency of detection 48 percent). Concentrations reported from 7.1 J µg/kg to 170 µg/kg (Table 5.2-19). Two results were reported at a concentration greater than 100 µg/kg, seven were between 10 and 100 µg/kg, and one result was less than 10 µg/kg. The mean BEHP concentration in this reach is 64 µg/kg (Tables 5.2-21 and 5.2-22).

5.2.6.3 BEHP in Subsurface Sediment

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Upriver Reach (RM 15.3 to 26)

Three subsurface sediment samples were collected and analyzed for BEHP between RM 15.4 and 16. BEHP was reported in all three samples, concentrations reported range from 20J to 3,800 µg/kg, with a mean of 1,300 µg/kg.

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Downtown Reach (RM 11.8 to 15.3)

BEHP was reported in 36 of 64 subsurface sediment samples within the Downtown reach (frequency of detection 56 percent). Concentrations reported range from 2.5J to 815 µg/kg with a mean of 103 µg/kg (Table 5.2-16a). Eight results were reported at concentrations greater than 100 µg/kg, 23 results were between 1 and 10 µg/kg, and five results were reported at a concentration less than 10 µg/kg (Table 5.2-17). None of the subsurface samples were collected in the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Within the Study Area, BEHP was reported in 635 of 1,591 subsurface samples (frequency of detection 40 percent). Concentrations reported range from 2.4J to 18,000 µg/kg (Table 5.2-2), with a mean of 345 µg/kg. The spatial distribution of BEHP concentrations in subsurface sediment are presented on Figure 5.2-17~~22~~ and Maps 5.2-18a-o.

Table 5.2-9 shows that there are two data points greater than 10,000 µg/kg. These are located in the navigation channel zone at RM 7.9 and 10.3. There are 32 detected values between 1,000 and 10,000 µg/kg, which are primarily located within the peak areas discussed above. Subsurface sediment samples greater than 1,000 µg/kg accounts for five percent of the detected data set. An additional 257 samples, 40 percent of the detected data set, were detected at concentrations between 100 and 1,000 µg/kg. Half of the detected data set (317 samples) is between 10 and 100 µg/kg. An additional 27 samples (four percent) is comprised of concentrations ranging between 1 and 10 µg/kg and there were no samples detected at a concentration less than 1 µg/kg.

Areas where BEHP concentrations greater than 1,000 µg/kg are observed in subsurface sediment are present in the eastern nearshore between RM 3.6 and 4.4 and in the International Terminals Slip, and in Swan Island Lagoon (Figure 5.2-17~~21~~, Map 5.2-18). Mean concentrations (Table 5.2-3) in these areas are 586 µg/kg at RM 3E-4E, 23,500 µg/kg at RM 4E-5E, and 650 µg/kg in Swan Island Lagoon.

Areas in the western nearshore zone where BEHP concentrations are greater than 1,000 µg/kg are observed from RM 6 through 10(Figure 5.2-17~~21~~ and Maps 5.2-18g,h,j,k). ~~The highest surface concentration detected in the Study Area was found at Station G367 at the mouth of Swan Island Lagoon.~~

~~Additional isolated occurrences of concentrations greater than 1,500 µg/kg were found. With few exceptions, these concentrations occurred outside the navigation channel, in the eastern and western nearshore zones.~~ The ~~most notable exception is the western side of the navigation channel at RM 10.3, where the highest subsurface~~maximum reported concentration of 18,000 µg/kg in subsurface sediment ~~in the Study Area~~ was ~~found~~ reported ~~in~~ from the interval of 0–195 cm bml at Station WR-VC-110 (RM 10.3). ~~A similarly elevated subsurface concentration was detected in the channel at RM 8 near the mouth of Swan Island Lagoon.~~Mean concentrations by river mile in this area are

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338 µg/kg at RM 6W-7W, 277 at RM 7W- 8W, 628 µg/kg at RM 8W-9W, and 359 µg/kg at RM 9W-10W (Table 5.2-6).

Within the navigation channel the highest concentrations of BEHP are observed at RM 7.9 (which appears most likely associated the reported concentrations in Swan Island Lagoon, Map 5.2-18i), and a single result at RM 10.3 near the western nearshore area (Map 5.2-18l). Mean BEHP concentrations in these areas are: 910 µg/kg for RM 7 to 8; and 502 µg/kg for RM 10 to 11 (Table 5.2-6).

Downstream Reach (RM 0 to 1.9)

BEHP was reported in 16 of 17 subsurface sediment samples les within the Downstream reach (frequency of detection 94 percent). Concentrations reported range from 3.1J to 39 µg/kg (Table 5.2-20). Five results were reported at concentrations greater than 10 µg/kg and eleven were less than 10 µg/kg. The mean concentration in this reach is 8.2 J µg/kg (Tables 5.2-21 and 5.2-22).

5.2.6.4 BEHP Surface and Subsurface Sediment Relationships

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Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach.

There are insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean BEHP surface sediment concentration in this reach is 94 µg/kg.

The surface BEHP sediment concentrations in the downtown reach are greater than the subsurface concentrations, and are 418 and 103 µg/kg, respectively.

Within the Study Area BEHP concentrations are generally greater in surface than in subsurface sediments, mean concentration are 1,050 and 345 µg/kg in surface and subsurface sediment, respectively (Tables 5.2-1 and 5.2-2). Exceptions to this general trend are observed in the eastern nearshore zone at RM 5E-6E where mean surface and subsurface concentrations are similar, and RM 8E-9E where the mean concentration in subsurface sediment is approximately twice that surface sediment (Tables 5.2-3 and 5.2-4). The maximum BEHP concentrations in surface and subsurface sediment in the eastern nearshore zone are both found in Swan Island Lagoon.

Within the western nearshore zone, localized areas where BEHP concentrations are greater in subsurface sediment include RM 5W-6W, where the mean subsurface concentration is an order of magnitude greater than the mean surface concentration, and RM 7W-8W, where mean surface and subsurface concentrations are similar. The maximum reported BEHP concentration in surface sediment in the western nearshore zone was located between RM 7W and 8W, while the maximum reported concentration in subsurface sediment was located between RM 5W and 6W.

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Within the navigation channel, the mean BEHP concentration in subsurface sediment at RM 7 to 8 is approximately three times the mean surface. The maximum reported surface and subsurface BEHP concentration in the navigation channel were reported at RM 10 to 11.

Within the downstream reach, mean BEAHP concentrations are greater in surface sediment (64 and 11 µg/kg in surface and subsurface sediment, respectively).

~~5.13.87.15~~5.2.7 Total Chlordanes in Sediment

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The distribution of total chlordanes concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-19; concentrations with depth at subsurface stations are depicted on Maps 5.2-20a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-19~~25~~ and 5.2-20~~6~~ present scatter plots of the total chlordanes data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

Summary statistics for total chlordanes in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2, surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present total chlordanes data by orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for detected-only values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-21~~7~~.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-42. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-2-; number of data points by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and nondetects).

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5.2.7.1 Total Chlordanes Data Set

The Study Area data set of total chlordanes concentrations includes 1,193 surface and 1,214 subsurface samples, the Upriver data set includes 77 surface and 3 subsurface samples, the downtown data set includes 145 surface and 94 subsurface samples, and the downstream data set includes 25 surface and 26 subsurface samples. Several nondetect results had reporting limits greater than the maximum reported concentrations (Figures 5.2-1925 and 5.2-2006), thus the majority of this discussion will focus on the detected values only as meaningful conclusions cannot be drawn from the elevated nondected values.

5.2.7.2 Total Chlordanes in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total chlordanes were detected in 38 of 77 surface sediment samples within the Upriver reach (frequency of detection 49 percent). Concentrations reported range from 0.06J to 1.5 µg/kg (Table 5.2-11). Two results were reported at a concentration greater than 1 µg/kg, the remaining 36 detections were all reported at concentrations less than 1 µg/kg (Table 5.2-13). The mean concentration in this reach is 0.39 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total chlordanes were reported in 110 of 145 surface sediment samples within the Downtown reach (frequency of detection 76 percent). Concentrations reported range from 0.04J to 23J µg/kg (Table 5.2-15a), the mean concentration is 1.3 µg/kg. The spatial distribution of total chlordanes in surface sediment within the Downtown reach is shown on Map 5.2-42.

Within the Downtown reach, total chlordane was reported at a concentration greater than 10 µg/kg in two results, 35 were between 1 and 10 µg/kg, and 73 results were reported at concentrations less than 1 µg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total chlordanes data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total chlordanes were reported in 761 of 1,193 surface sediment samples within the Study Area (frequency of detection 64 percent). Concentrations reported range from 0.03J to 669 NJ µg/kg (Table 5.2-1), with a mean concentration in surface sediment of 5 µg/kg. The spatial distribution of reported chlordane concentrations in surface sediment within the Study Area is presented on Figure 5.2-1925.

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Areas in the eastern nearshore zone where reported concentrations greater than 10 µg/kg are reported were observed at RM 2.8, RM 3.8, RM 5.5, Swan Island Lagoon, and RM 11 (Figure 5.2-1925 and Map 5.2-19). The highest surface concentration detected in the eastern nearshore zone (60 µg/kg) was found at Station GCA11E at RM 11. Mean concentrations in these areas are 1.15 µg/kg at RM 2E-3E, 1.48 µg/kg at RM 3E-4E, 2.37 µg/kg at RM 5E-6E, 2.75 µg/kg in Swan Island Lagoon, and 11.4 µg/kg at RM 11E -11.8E (Table 5.2-3).

Areas in the western nearshore zone were reported total chlordane concentrations greater than 10 µg/kg were observed from RM 5.8W through 9W (Figure 5.2-1921). Overall, detected concentrations of total chlordanes were below 5 µg/kg throughout most of the Study Area (Maps 5.1-13 and 5.1-14a–m, see frequency plot inset) and, with few exceptions, were generally lower along the navigation channel (Figures 5.1-17 and 5.1-18; Tables 5.1-1 and 5.1-2). Sediment concentrations greater than 5 µg/kg were detected at several locations throughout the Study Area, but occurred most extensively along the western nearshore zone between approximately RM 6 and 7.4 (Maps 5.1-13 and 5.1-14a–m).

Frequencies of detection were 64 percent and 55 percent, respectively, for surface and subsurface samples. Approximately ninety-five percent of the surface samples were below 12.2 JV µg/kg. The maximum reported concentration in surface concentration sediment of 669NJ µg/kg was found at Station G355 (RM 7.3W). Another cluster of concentrations greater than 5 µg/kg in surface and subsurface samples occurred at RM 8.8W and at the head of the International Terminals Slip (RM 3.7E; some areas have subsequently been dredged). Mean concentrations in the western nearshore zone are 1.75 µg/kg at RM 5W-6W, 12.5 µg/kg at RM 6W-7W, 24.9 µg/kg at RM 7W-8W, and 28.9 µg/kg at RM 8W-9W. Within the navigation channel there were no reported concentrations greater than 10 µg/kg (Table 5.2-7).

Table 5.2-9 shows that there are three detected data points in surface sediment Total chlordane concentrations greater than 100 µg/kg were reported in three results, 46 were between 10 and 100 µg/kg, 270 detected results were between 1 and 10 µg/kg, and 442 results (58 percent of detections) were reported at concentrations less than 1 µg/kg.

Downstream Reach (RM 0 to 1.9)

Total chlordanes were reported in 15 of 25 surface sediment samples within the Downstream reach (frequency of detection 60 percent). Concentrations reported range from 0.07NJ to 4.5J µg/kg (Table 5.2-19). Three results were reported at a concentration greater than 1 µg/kg, the remaining 12 results were all less than 1 µg/kg (Table 5.2-21), with a mean of 0.8 µg/kg.

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5.2.7.3 Total Chlordanes in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Only three subsurface sediment samples were analyzed for total chlordane in the upriver reach, all collected between RM 15.4 and 16. Chlordanes were reported in all three results, from 0.2 to 1.3 µg/kg, with a mean of 0.89 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total chlordanes were reported in 51 of 94 subsurface sediment samples within the Downtown reach (frequency of detection 54 percent). Concentrations reported range from 0.09J to 54 µg/kg (Table 5.2-16a), with a mean concentration of 3.2 µg/kg. ~~shows that t~~There are two values detected above 10 µg/kg. Total chlordane was reported at concentrations between 1 and 10 µg/kg in 26 results, the remaining 23 results were reported at concentrations less than 1 µg/kg (Table 5.2-17). ~~-~~No subsurface samples were collected from the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Total chlordanes were reported in 648 of 1,214 subsurface samples (frequency of detection53 percent) within the Study Area. Concentrations reported range from 0.04J to 2,330J µg/kg (Table 5.2-2), with a mean concentration of 20 µg/kg. The spatial distribution of total chlordane in subsurface sediment is presented on Figure 5.2-20~~6~~ and Maps 5.2-20a-o.

Areas in the eastern nearshore zone where total chlordane in subsurface sediment was reported at concentrations greater than 10 µg/kg are were observed at RM 2.2E, RM 3.8E, RM 5.5E, Swan Island Lagoon, at RM 11E (Figure 5.2-20~~6~~ and Map 5.2-20a-o). The highest total chlordane concentration of 490 µg/kg in subsurface sediment reported in the eastern nearshore zone was at Station C092 at RM 3.8E. Mean total chlordane concentrations by river mile are 2.26 µg/kg at RM 2E-3E, 31.2 µg/kg at RM 3 E-4E, 4.67 µg/kg at RM 5E-6E, 15.5 µg/kg in Swan Island Lagoon, and 23.5 µg/kg for RM 11E-11.8E (Table 5.2-3).

Total chlordane concentrations greater than 10 µg/kg in the western nearshore zone from RM 4.5 through 9. ~~A sample collected~~The highest reported total chlordane concentration of 2,330J µg/kg in subsurface sediments was reported at RM 8.8 ~~contained the highest subsurface concentration of total in the Study Area (~~at Station C455 in the interval of 30–152 cm bml~~)~~ (~~.~~ Figure 5.2-20~~1~~). Mean concentrations 5.79 µg/kg for RM 4W-5W, 17.2 µg/kg at RM 5W-6W, 18.9 µg/kg at RM 6W-7W, 68.5 µg/kg at RM 7E-8E, 61.4 µg/kg at RM 8E-9E (Table 5.2-8).

~~This same core sample contained the maximum concentrations of total PCBs and total PCDD/Fs in the Study Area.~~

The highest reported concentrations of chlordane in subsurface sediment in the navigation channel were observed RMs 6.5, 10.3 and 11.3. Chlordane concentrations

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at RM 6.5 appear associated with observed contamination in the western nearshore zone (Map 5.2-20g), concentrations at RM 11.3 are most likely associated the contamination noted at RM 11E (Maps 5.2-20n,o). Mean concentrations are 1.94 µg/kg at RM 6-7, 2.83 µg/kg for RM 10-11, and 7.82 at RM 11-11.8 (Table 5.2-6).

Total chlordane was reported at a concentration greater than 1,000 µg/kg in one result, 19 were between 100 and 1,000 µg/kg, 67 results were reported at concentrations between 10 and 100 µg/kg, 316 were between 1 and 10 µg/kg, and 245 results were reported at concentrations less than 1 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Total chlordanes were reported in 5 of 26 subsurface sediment samples within the Downstream reach (frequency of detection 19 percent). Concentrations reported range from 0.75NJ to 2.2NJ µg/kg (Table 5.2-20). Four results were reported at a concentration greater than 1 µg/kg and one sample was reported at less than 1 µg/kg, with a mean in of 1.5 µg/kg (Tables 5.2-21).~~Except for elevated detections from RM 10 to 10.2 and RM 11.2 to 11.6, peaks in the navigation channel were typically located near elevated concentrations in the nearshore.~~

5.2.7.4 Total Chlordanes Surface and Subsurface Sediment Relationships

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Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean total chlordanes surface sediment concentration in this reach is 0.39 µg/kg (Table 5.2-11).

Within the downtown reach the mean total chlordane concentration in surface sediment is 1.3 µg/kg and 3.2 µg/kg subsurface sediment (Tables 5.2-15a and 5.2-16a).

Within the Study Area, total chlordane concentrations are greater in the subsurface sediments. The mean concentration in surface and subsurface sediments is 5 and 20 µg/kg, respectively (Tables 5.2-1 and 5.2-2). As shown on Figure 5.2-21~~7~~, mean concentrations are greater in the nearshore areas than in the navigation channel, and the western nearshore zone is greater than the eastern nearshore zone.

In the eastern nearshore zone, total chlordane concentrations are greater in subsurface than in surface sediment in all river mile except RM 10 to 11. In the western nearshore zone, subsurface sediment concentrations are greater in all river miles except RM 1.9 to 3. Within the navigation channel total chlordane in subsurface sediment is greater than the surface sediment concentrations except from RM 1.9 to RM 4. Areas where the highest chlordane concentrations are observed generally align between surface and subsurface sediment.

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Within the downstream reach, the mean total chlordane concentrations are 0.8 µg/kg and 1.5 µg/kg in surface and subsurface sediment, respectively (Tables 5.2-19 and 5.2-20).

~~5.13.87.16~~5.2.8 Aldrin and Dieldrin in Sediment

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The insecticides~~,~~ aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin ~~quickly~~ readily undergoes biotic and abiotic transformation~~breaks down~~ to ~~into~~ dieldrin ~~in the~~. However, because aldrin is not converted to dieldrin under anaerobic conditions, it is unlikely that aldrin is converted to dieldrin in sediments but may do so within other media that will be discussed in subsequent sections.

The distribution of aldrin and dieldrin concentrations at each surface sediment sampling station throughout the Study Area is depicted on Maps 5.2-21 and 5.2-23; concentrations with depth at subsurface stations are depicted on Maps 5.2-22a-o and 5.2-24a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two results is presented on these maps; all subsurface samples are presented.

Figures 5.2-22~~9~~ and 5.2-23~~30~~ present scatter plots of the aldrin data set for surface and subsurface sediment in the Study Area, respectively. Figures 5.2-25~~33~~ and 5.2-26~~34~~ present scatter plots of the die~~a~~ldrin data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for aldrin and dieldrin in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present aldrin and dieldrin results as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figures 5.2-24~~31~~ (for aldrin) and 5.2-27~~35~~ (for dieldrin).

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Maps 5.2-43 and 5.2-44. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics for

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surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-2-; number of data points by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and nondetects).

5.2.8.1 Aldrin and Dieldrin Data Sets

The Study Area data set for aldrin consists of 1,146 surface and 1,272 subsurface samples, 77 surface and 3 subsurface samples from the Upriver reach, 145 surface and 94 subsurface samples from the downtown reach, and 25 surface and 26 subsurface samples from the downstream reach.

The Study Area data set for dieldrin consists of 1,190 surface and 1,208 subsurface samples, 77 surface and 3 subsurface samples from the Upriver reach, 145 surface and 94 subsurface samples from the downtown reach, and 25 surface and 26 subsurface samples from the downstream reach.

Data quality issues resulted in high detection limits for several aldrin and dieldrin results within the Study Area (Figures 5.2-22~~9~~ and 5.2-23~~30~~ for aldrin, Figures 5.2-25~~33~~ and 5.2-26~~34~~ for dieldrin); thus, the majority of this discussion will focus on the detected values only since meaningful conclusions cannot be drawn from the elevated nondetect values.

5.2.8.2 Aldrin and Dieldrin in Surface Sediment

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Upriver Reach (RM 15.3 to 28.4)

Aldrin was reported in seven of 77 surface sediment samples within the Upriver reach (detection frequency of nine percent). Concentrations reported range from 0.17J to 0.55 µg/kg (Table 5.2-11, Table 5.2-13) with a mean concentration of 0.33 µg/kg.

Dieldrin was reported in 10 of 77 surface sediment samples (frequency of detection 13 percent), concentrations reported range from 0.09NJ to 0.4 µg/kg (Table 5.2-11, Table 5.2-13) with a mean concentration of 0.2 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

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Aldrin was reported in 22 of 145 surface sediment samples within the Downtown reach (frequency of detection 15 percent). Concentrations reported range from 0.07J to 0.7NJ µg/kg (Table 5.2-15a, Table 5.2-17) with a mean concentration of 0.26 µg/kg.

Dieldrin was reported in 14 of 145 surface sediment within the Downtown reach (frequency of detection ten percent). Concentrations reported range from 0.04J to 1.1 µg/kg (Table 5.2-15a, Table 5.2-17) with a mean concentration of 0.27 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the

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Downtown data set. None of the aldrin or dieldrin data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Aldrin was reported in 268 of 1,146 surface sediment samples within the Study Area (frequency of detection 23 percent). Concentrations reported range from 0.003J to 691J µg/kg (Table 5.2-1), with a mean concentration of 5 µg/kg. The spatial distribution of aldrin in surface sediment in the Study Area is presented on Figure 5.2-229.

Dieldrin was reported in 252 of 1,190 surface sediment samples within the Study Area (frequency of detection 21 percent). Concentrations reported range from 0.008 to 356J µg/kg (Table 5.2-1) with a mean concentration of 3 µg/kg. The spatial distribution of dieldrin in surface sediment is presented on Figure 5.2-2533.

Aldrin was not reported at a concentration greater than 10 µg/kg in surface sediment within the eastern nearshore zone (Figure 5.2-229), areas were reported concentrations greater than 1 µg/kg are noted in the eastern nearshore zone from RM 2 to 4, RM 5.8 to 6.2, and in Swan Island Lagoon. The highest reported concentration in surface sediment of 6 µg/kg aldrin in the eastern nearshore zone was at Station PSY01 in Swan Island Lagoon. Mean aldrin concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are 0.9 µg/kg at RM 1.9E-3E, 0.5 µg/kg at RM 3E-4E, 0.9 µg/kg at RM 5E-6E, and 1.0 µg/kg in Swan Island Lagoon.

Detected concentrations of dieldrin greater than 10 µg/kg in surface sediment were observed only in Swan Island Lagoon (Figure 5.2-2533). Concentrations greater than 1 µg/kg were observed in the same pattern as aldrin, with the addition of RM 11 to 11.8 in the eastern nearshore zone. The highest reported concentration of dieldrin in surface sediment in the eastern nearshore zone (22 µg/kg) is located at Station M0201 in Swan Island Lagoon. Mean concentrations of dieldrin (Table 5.2-3) in these areas in the eastern nearshore zone are 0.8 µg/kg at RM 1.9E-3E, 0.2 µg/kg at RM 3E-4E 1.2 µg/kg at RM 5E-6E, 4.4 µg/kg in Swan Island Lagoon, and 4.4 µg/kg at RM 11E-11.8E.

Aldrin at concentrations greater than 10 µg/kg was reported in the western nearshore zone in from RM 6.8 through 7.2 and at RM 8.8. Reported concentrations greater than 100 µg/kg were observed at RMs 7.3 and 8.8 (Figure 5.2-2229). The maximum concentration of aldrin in surface sediment (691J µg/kg) is located at Station G355 (RM 7.3W). Concentrations greater than 1 µg/kg were observed from RM 3W through RM 10W. Mean concentrations by river mile in the western nearshore zone are 0.6 µg/kg at RM 3W-4W, 0.6 at RM 4W-5W, 1.0 µg/kg at RM 5W-6W, 3.4 µg/kg at RM 6W-7W, 40 µg/kg at RM 7W-8W, 14 µg/kg at RM 8W-9W, and 1.0 µg/kg at RM 9W-10W (Table 5.2-7).

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Dieldrin was reported at concentrations greater than 10 µg/kg in the western nearshore zone at RM 6.3W, RM 7.3W and RM 8.3W through 8.8W. Reported concentrations greater than 100 µg/kg were noted at RM 8.8W (Figure 5.2-2533). The maximum reported concentration of dieldrin (356J µg/kg) is located at Station G453 (RM 8.8W). Concentrations greater than 1 µg/kg are observed at RM 3.3W, from RM 5.5W through 9.8W, and at RM 11.3W. Mean concentrations by river mile are 0.3 µg/kg at RM 3W-4W, 0.4 µg/kg at RM 5W-6W, 1.8 µg/kg at RM 6W-7W, 2.9 µg/kg at RM 7W-8W, 29 µg/kg at RM 8W-9W, and 2.5 µg/kg at RM 11W-11.8W (Table 5.2-7).

Neither aldrin nor dieldrin were detected in the navigation channel at concentrations greater than 10 µg/kg (Figures 5.2-229 and 5.2-2533). Concentrations of aldrin greater than 1 µg/kg were observed from RM 2 to 3, RM 5 to 7.5, and at RM 9.3. Mean concentrations (Table 5.2-5) in these areas are: 0.7 µg/kg at RM 1.9-3, 1.2 µg/kg at RM 5-6, 0.81 µg/kg at RM 6-7, and 0.7 µg/kg at RM 9-10. Dieldrin was reported at concentrations greater than 1 µg/kg at RM 5.6 and RM 6.4. Mean concentrations in these areas are 0.7 at RM 5-6 and 0.5 µg/kg at RM 6-7.

Aldrin was reported at a concentration greater than 100 µg/kg in surface sediment in two results, 12 detected were between 10 and 100 µg/kg, 67 results were between 1 and 10 µg/kg, 187 (70 percent) were reported at concentrations less than 1 µg/kg (Table 5.2-9).

A single dieldrin result was reported at a concentrations greater than 100 µg/kg in surface sediment, six were between 10 and 100 µg/kg, 33 were reported at concentrations between 1 and 10 µg/kg, 212 samples (84 percent) were less than 1 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Aldrin was reported in 3 of 25 surface sediment samples within the Downstream reach (frequency of detection 12 percent). Concentrations reported range from 0.37J to 0.4J µg/kg (Table 5.2-19, Table 5.2-21) with a mean of 0.4 µg/kg. Dieldrin was reported in one of 25 surface sediment samples a concentration of 0.07J µg/kg.

5.2.8.3 Aldrin and Dieldrin in Subsurface Sediment

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Upriver Reach (RM 15.3 to 26)

Aldrin and dieldrin were not detected in the three subsurface sediment samples collected between RM 15.4 and. Detection limits ranged up to was 0.2 µg/kg for aldrin and 0.036 µg/kg for dieldrin (Table 5.2-12).

Downtown Reach (RM 11.8 to 15.3)

Aldrin was reported in 8 of 94 subsurface sediment samples within the Downtown reach (frequency of detection nine percent). Concentrations reported range from 0.08J to 1.7 µg/kg (Table 5.2-15a) with a mean concentration of 0.41 µg/kg. With the exception of the 1.7 µg/kg, result, all reported values were less than 1 µg/kg (Table 5.2-17).

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Dieldrin was reported in 4 of 94 subsurface sediment samples (frequency of detection four percent), concentrations reported range from 0.29J to 16J µg/kg (Table 5.2-15a, Table 5.2-17), with a mean concentration of 7 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the aldrin or dieldrin data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Aldrin was reported in 135 of 1,172 subsurface sediment samples within the Study Area (frequency of detection 12 percent), concentrations reported range from 0.11J µg/kg to 1,340J µg/kg (Table 5.2-1), with a mean of 5 µg/kg. The spatial distribution of aldrin in subsurface sediment within the Study Area is presented on Figure 5.2-2330.

Dieldrin was reported in 77 of 1,208 subsurface sediment (frequency of detection six percent). Concentrations reported range from 0.04NJ to 100J µg/kg (Table 5.2-1), with a mean of 4 µg/kg. The spatial distribution of dieldrin in subsurface sediment also is presented on Figure 5.2-2634.

The maximum reported concentration (3.81NJ µg/kg) of aldrin in subsurface sediment in the eastern nearshore zone was at Station C019-1 at RM 2.3E. Concentrations greater than 1 µg/kg were observed from RM 1.9E to 5.6E and at RM 11.2E (Figure 5.2-2330). Mean concentrations by river mile are 1.0 µg/kg at RM 1.9E-3E, 0.7 µg/kg at RM 3E-4E, 0.7 µg/kg at RM 4E-5E, 0.9 µg/kg at RM 5E-6E and 1.8 µg/kg at RM 11E to 11.8E (Table 5.2-4).

Dieldrin was reported in subsurface sediment at a maximum concentration- of 100 µg/kg in the eastern nearshore zone at RM 3.7E (Station C092; 30–152 cm bml) at the head of the International Terminals Slip (Figure 5.2-2634; Table 5.2-4).

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Detected concentrations of both chemicals were generally less than 1 µg/kg (Maps 5.1-15 through 5.1-18, see frequency plot inset), though higher concentrations occurred at several locations scattered along the nearshore zones and navigation channel (Figures 5.1-19 through 5.1-22).

Frequencies of detection for aldrin were low, 23 percent for surface samples and only 13 percent for subsurface samples (Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were below 10.6 JV µg/kg. The most prominent area of detected maximum reported aldrin concentrations in subsurface sediment (1,340 J µg/kg) was in the western nearshore zone was observed at RM 7.4W at Station C356, 136–256 cm bml (Figure 5.2-2330). Aldrin concentrations in sediment greater than 1 µg/kg are observed from 4.5 to RM 8.8, concentrations greater than 10 µg/kg were observed from

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RM 6.1 through RM 8.8, and , where the maximum surface (Station C355) and subsurface (Station C356, 136-256 cm bml) concentrations were detected. Concentrations greater than 1 µg/kg extended downstream along the western shoreline to approximately RM 5.2 (Maps 5.1-15 and 5.1-16a-m).

Two other prominent aldrin peaksreported concentrations greater than 100 µg/kg are shown by the data, one indicated by concentrations exceeding 100 µg/kg)were reported in two (in surface and subsurface samples at RM 6.1W and RM 8.8W , the other indicated by concentrations approaching 100 µg/kg in the subsurface from approximately RM 6 to 6.5 (Figures 5.1-19 and 5.1-205.2-2330). Mean concentrations in these areas are 0.9 µg/kg at RM 4W-5W, 1.9 µg/kg at RM 5W-6W, 29 µg/kg at RM 6W-7W 73 µg/kg at RM 7W-8W, and 68 µg/kg at RM 8W-9W (Table 5.2-8). Reported dieldrin concentrations greater than 10 µg/kg in the western nearshore zone occur between RM 6W and 8.8W (Figure 5.2-2634), mean concentrations in these areas are: 4.5 µg/kg at RM 6W -7W; 4.0 µg/kg at RM 7W-8W, and 17.3 µg/kg at RM 8W-9W (Table 5.2-8).Some of these data are N-qualified.

Within the navigation channel, Aldrin concentrations greater than 10 µg/kg were noted at RM 6.4, sediment concentrations above greater than 1 µg/kg were detected from RM 6 to 7 and at several locationsRM 10.3 within the navigation channel (Figure 5.2-2330). The maximum concentration ofreported aldrin concentration (44J µg/kg) within the navigation channel occurred was observed in the interval of 30 to 137 cm bml at core Station C29906 (approximately RM RM 6.45.6 near the east west bank). Mean concentrations in these areas are 13 µg/kg at RM 6-7, and 0.7 µg/kg at RM 10-11(Table 5.2-6).This same interval also recorded high concentrations for PAHs, arsenic, chromium, copper, lead, mercury, zinc, and PCBs. Aldrin concentrations above 1 µg/kg were also detected in the navigation channel in the RM 11.2-11.5, 10-10.2, and 8.6-8.9 reaches.

Frequencies of detection for dieldrin were even lower, 21 percent for surface samples and only 7 percent for subsurface samples. Ninety-five percent of the surface samples were below 5.93 JV µg/kg. Dieldrin concentrations above 1 µg/kg were detected in subsurface samples collected along the eastern nearshore between RM 3.8 and 4, where the highest subsurface concentration in the Study Area was found at Station C092 (30-152 cm bml; N-qualified) at the head of the International Terminals Slip (Maps 5.1-17 and 5.1-18a-m). Dieldrin concentrationswas reported at a concentration greater than 10 µg/kg in only one sample located within the navigation channel at Station WR-CD-40 (13 µg/kg) near RM 11.3. Concentrations above 1 µg/kg µg/kg were also detected reported in several cores collected at RM 3.5, 6.1, and 11.2 in the navigation channel downstream from the Broadway Bridge. Mean concentrations in these areas are 0.8 µg/kg at RM 3-4, 3.0 µg/kg at RM 6-7, and 5.6 µg/kg at RM 11-11.9 (Table 5.2-6).Along the western shoreline, dieldrin concentrations above 1 µg/kg were detected in the RM 8.5-8.8 reach, at RM 7.4, and between RM 5.7 and 6.6 (Figures 5.1-

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~~21 and 5.1-22). The maximum surface sediment concentration of dieldrin in the Study Area was found at Station C453 located in the western nearshore zone at RM 8.8.~~

Downstream Reach (RM 0 to 1.9)

Aldrin was reported in 3 of 26 subsurface sediment samples within the Downstream reach (frequency of detection 12 percent). Reported concentrations range from 0.2J to 2.8NJ µg/kg (Table 5.2-19), with a mean of 1.2 µg/kg. Dieldrin was not reported within the Downstream reach.

5.2.8.4 Aldrin and Dieldrin Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentration by reach and also by subareas within the Study Area reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. Mean concentrations in surface sediment are 0.33 and 0.2 µg/kg for aldrin and dieldrin, respectively.

Within the Downtown reach, mean aldrin and dieldrin concentrations were greater in subsurface versus surface sediment. Mean surface and subsurface concentrations 0.26 and 0.41 µg/kg for aldrin, and 0.27 and 7 µg/kg for dieldrin, respectively.

Within the Study Area, aldrin and dieldrin concentrations are also generally greater in subsurface than in surface sediments. Study Area-wide, mean surface and subsurface concentrations are 4.9 and 23 µg/kg for aldrin and 2.6 and 3.6 µg/kg for dieldrin. Exceptions to this general trend are noted in the western nearshore zone at RM 9W-10W where the mean aldrin concentration is greater in surface sediment, at RM 8W-9W where the mean dieldrin concentration is greater in surface sediment, and at RM11-11.8W where both aldrin and dieldrin mean concentrations are greater in surface sediment (Figures 5.2-24 and 27~~35~~).

In Swan Island Lagoon, the mean aldrin and dieldrin concentrations are greatest in surface sediment. Mean dieldrin in surface sediment are greater at RM 1.9E to 3E, RM 5E to 6E. Within the navigation channel, mean aldrin and dieldrin concentrations in surface sediment concentrations are greater than in subsurface sediment.

Insufficient data are available in the Downstream reach to allow meaningful comparisons between surface and subsurface sediment concentrations.

~~5.13.87.17~~5.2.8.5 Arsenic in Sediment

The distribution of arsenic concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-25; concentrations with depth at subsurface stations are depicted on Maps 5.2-26a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps, all subsurface samples are presented.

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Figures 5.2-2837 and 5.2-2938 present scatter plots of the arsenic data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

Summary statistics for arsenic in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2, respectively. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present arsenic data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-3039.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-45. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20, number of data points by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and nondetects).

5.2.8.6 Arsenic Data Set

Arsenic results includes 1,551 surface and 1,553 subsurface samples from within the Study Area, 77 surface and 3 subsurface samples from the Upriver reach, 233 surface and 178 subsurface samples from the downtown reach, and 25 surface and 26 subsurface samples from the downstream reach.

5.2.8.7 Arsenic in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Arsenic was reported in 73 of 77 surface sediment samples within the Upriver reach (frequency of detection 95 percent). Concentrations ranging from 1.9J mg/kg to 5.3 mg/kg (Table 5.2-11), with a mean of 2.9 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

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Arsenic was reported in 201 of 233 surface sediment within the Downtown reach (frequency of detection 86 percent). Concentrations reported range from 1.1 to 126J

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mg/kg (Table 5.2-15a), with a mean concentration of 6.2 mg/kg. The spatial distribution of arsenic within the Downtown reach is presented on Map 5.2-45. The majority of results are less than 5 mg/kg, localized areas with concentrations greater than 25 mg/kg were observed at RM 13 on the eastern shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

One result was reported at a concentration greater than 100 mg/kg, 17 results were between 10 and 100 mg/kg, 183 results (91 percent of the detected data set) were less than 10 mg/kg, and no detected results were reported at concentrations less than 1 mg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Arsenic was reported in 74 surface sediment samples within the Zidell action area, reported concentrations range from 1.3 to 78J mg/kg (Table 5.2-15c). The mean arsenic concentration for this area is 11.2 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of arsenic concentrations in surface sediment is from 1.1 to 126 mg/kg with a mean concentration of 4.7 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Arsenic was reported in 1,426 of 1,551 surface sediment samples within the Study Area (frequency of detection 92 percent). Concentrations reported range from 0.7 to 132 mg/kg (Table 5.2-1), with a mean of 4.5 mg/kg. The spatial distribution of arsenic concentrations within the Study Area is presented on Figure 5.2-2837.

Within the eastern nearshore zone, sediment concentrations approaching or greater than 100 mg/kg were observed identified in the eastern nearshore zone at RM 2.3E, RM 5.6E, and RM 7.2E (Figure 5.2-2837). Areas where concentrations are greater than 10 mg/kg occur at RM 5.5E, RM 7E, and in Swan Island Lagoon (Figure 5.2-2837, Map 5.2-25). The highest surface concentration detected in the eastern nearshore zone (132 mg/kg) was found at Station RB08 at RM 2.3. Mean concentrations (Table 5.2-3) for these areas are: 5.8 mg/kg at RM 1.9E-3E, 7.0 mg/kg at RM 5E-6E, 7.2 mg/kg at RM 7E-8E, and 5.9 mg/kg in Swan Island Lagoon.

Areas in the western nearshore zone where arsenic concentrations exceed 10 mg/kg occur from RM 3.5W through 7W, RM 8.3W to 9.2W, and at RM 10.2W. Three localized areas where reported concentrations are greater than 50 mg/kg are located at RM 6.8W, RM 8.6W (80 mg/kg at Station A2GS10), and RM 10.2W (Figure 5.2-2837). Mean concentrations in these areas are 4.9 mg/kg at RM 3W-4W, 4.1 mg/kg at RM 4W-5W, 4.1 mg/kg for RM 5W-6W, 6 mg/kg at RM 6W-7W, 9.2 mg/kg at RM 8W-9W, 5.8 mg/kg at RM 9W-10W, and 10 mg/kg at RM 10W-11W (Table 5.2-7). There were no

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reported arsenic concentrations in surface sediment exceeding 10 mg/kg in the navigation channel

Within the Study Area, arsenic was reported in surface sediment at a concentration greater than 100 mg/kg in two results, 57 were between 10 and 100 mg/kg,1,364 (96 percent of the detected results) were reported at concentrations between 1 and 10 mg/kg, and three were reported at concentrations less than 1 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Arsenic was reported in all 25 surface sediment samples within the Downstream reach, concentrations reported range from 0.6J to 6.4 mg/kg (Table 5.2-19). One result was reported at a concentration less than 1 mg/kg, the remaining 24 results were between 1 and 10 mg/kg (Table 5.2-21). The mean arsenic concentration in this reach is 3.7 mg/kg.

5.2.8.8 Arsenic in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Arsenic was analyzed and reported in only three subsurface samples between RM 15.4 and 16. Concentrations reported range from 2.4 to 2.5 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Arsenic was reported in 168 of 178 subsurface sediment samples within the Downtown reach (frequency of detection 94 percent). Concentrations reported from 0.57 mg/kg to 7.5 mg/kg (Table 5.2-16a), with a mean of 3.0 mg/kg. The majority of the results (165 samples) were reported at concentrations between 1 and 10 mg/kg, the remaining three results were reported at concentrations less than 1 mg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. Arsenic was analyzed in 30 subsurface sediment samples within the Zidell action area, reported concentrations range from 2 to 7.5 mg/kg, with a mean concentration in this area of 3.5 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-16c), the range of reported concentrations in subsurface sediment is 0.57 to 7.2 mg/kg, with a mean of 2.9 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Arsenic was reported in 1,489 of 1,553 subsurface samples within the Study Area (frequency of detection 96 percent). Concentrations reported range from 0.5J to 51 mg/kg (Table 5.2-2) with a mean of 4.1 mg/kg. The spatial distribution of reported arsenic concentrations in subsurface sediment is presented on Figure 5.2-29~~38~~ and Maps 5.2-26a-o).

Within the eastern nearshore zone, arsenic concentrations in subsurface sediment exhibits a different pattern than observed in surface sediment (Figure 5.2-30~~26~~).

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Concentrations greater than 10 mg/kg occur at RM 3.6E, RM 4.6E, RM 5.6E, RM 8.5E, RM 11.3E, and in Swan Island Lagoon (Figure 5.2-2938 and Map 5.2-26a-o). Single points are noted at RM 6.7 and RM 7.4. The highest reported subsurface concentration of 51 mg/kg was ~~found~~ observed in the interval of 150–236 cm bml at Station C708 ,near the mouth of Swan Island Lagoon. Mean concentrations in these areas are 3.6 mg/kg at RM 3E-4E, 3.5 mg/kg at RM 4E-5E, 5.4 mg/kg at RM 5E-6E, 4.1 mg/kg at RM 6E-7E, 4.1 mg/kg at RM 7E-8E, 11.8 mg/kg at RM 8E-9E, 4.8 mg/kg in Swan Island Lagoon, and 4.7 mg/kg at RM 11E-11.8E (Table 5.2-3).

Arsenic concentrations greater than 10 mg/kg were reported in the western nearshore zone from RM 3.6W through 9.2W, most prominently between RM 8.6W and 9.2W (Figure 5.2-2938). The maximum reported value in the western nearshore zone was 43.3 mg/kg at Station HA-38 at RM 9.0. Mean concentrations in this area are 6.1 mg/kg at RM 3W-4W, 4.0 mg/kg at RM 4W-5W, 4.2 mg/kg at RM 5W-6W, 3.6 mg/kg at RM 6W-7W, 4.3 mg/kg at RM 7W-8W, 5.7 mg/kg at RM 8W-9W, and 8.1 mg/kg at RM 9W to 10W (Table 5.2-8).

Only three results from within the navigation channel were reported at a concentration greater than 10 mg/kg, at RM 7.9, 10.3 and 11.5. Within these areas, mean arsenic concentrations are 4.2 mg/kg at RM 7-8; 4.0 mg/kg at RM 10-11, and 3.03 mg/kg at RM 11-11.8 (Table 5.2-6).

Of the reported arsenic concentrations in subsurface sediment, 45 results were greater than 10 mg/kg, 1,433 results (96 percent of the reported results) were between 1 and 10 mg/kg, and 11 were reported at concentrations less than 1 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Arsenic was reported in all 26 subsurface sediment samples collected within the Downstream reach, with reported concentrations ranging from 0.6 J mg/kg to 13 mg/kg (Table 5.2-20). Table 5.2-21 shows that there is one sample detected at a concentration greater than 10 mg/kg. The majority of the samples (24 samples; 92 percent) were detected at concentrations between 1 and 10 mg/kg. Only one sample was detected at a concentration less than 1 mg/kg. The mean arsenic concentration in this reach is 4.1 mg/kg.

5.2.8.9 Arsenic Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach, and also by subareas with the Study Area reach. There are insufficient data to allow for a meaningful comparison of surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean arsenic surface sediment concentration in this reach is 2.9 mg/kg (Table 5.2-11).

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Surface sediment concentrations in the downtown reach were greater than the subsurface concentrations, indicating that there may be ongoing sources in this reach. The mean surface concentration is 6.2 mg/kg, while the mean subsurface sediment concentration is 3.0 mg/kg (Tables 5.2-15a and 5.2-16a).

Arsenic concentrations are also generally greater in the surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 4.5 mg/kg and the mean subsurface sediment concentration is 4.1 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-30~~9~~ shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the western nearshore zone is slightly greater than the eastern nearshore zone. It also shows that concentrations are generally greater in the surface sediment than in subsurface sediment.

In the eastern nearshore zone, surface sediment is greater than subsurface sediment in all river mile zones except RM 8 to 9 and RM 11 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles except RM 4 to 5, RM 6 to 7, RM 8 to 9, and possibly RM 10 to 11. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations.

Areas where subsurface sediment concentrations are elevated do not align with the locations where surface sediment concentrations are elevated. The most prominent areas are RM 8 to 9 in the eastern nearshore zone, and RM 8 to 9 and RM 10 to 11 in the western nearshore zones. Additional areas with elevated concentrations are RM 1.9 to 3, RM 5 to 6, RM 7 to 8, and Swan Island lagoon in the eastern nearshore zone, and RM 3 to 4, RM 6 to 7, and RM 8 to 10 in the western nearshore zone (Figure 5.2-30~~9~~).

The surface sediment concentrations in the downstream reach were greater than subsurface concentrations. The mean surface concentration is 4.1 mg/kg, while the mean subsurface concentration is 3.8 mg/kg (Tables 5.2-19 and 5.2-20)

~~5.13.87.185~~5.2.9 Chromium in Sediment

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The distribution of chromium concentrations in surface sediment throughout the Study Area is depicted on Map 5.2-27, subsurface results are depicted on Maps 5.2-28a-o. If more than one sample was analyzed from the same surface sediment location, the greater of the two results is presented; all subsurface samples are presented.

Scatter plots of the chromium data from within the Study Area are presented on Figures 5.2-3~~4~~1 and 5.2-3~~4~~2, respectively, for surface and subsurface sediment segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

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Summary statistics for surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Chromium results by orders of magnitude (<1, 1-10, 10-100, 100-1,000, etc.) are presented for detected values in Table 5.2-9, and for combined detected and nondetect results in Table 5.2-10. A histogram of average surface and subsurface sediment values by river mile and for the Study Area is presented on Figure 5.2-343.

Results for the Upriver, Downtown, and Downstream reaches are presented in statistical tables and order of magnitude tables. Additionally, surface sediment results for the Downtown reach are presented in Map 5.2-46. Summary statistics for surface and subsurface sediment results within the Upriver reach are shown in Tables 5.2-11 and 5.2-12, respectively. Results by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics for surface and subsurface sediment results within the Downtown reach are shown in Tables 5.2-15 and 5.2-16, respectively, the number of results by order of magnitude are provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20, respectively, the number of results by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and nondetects).

5.2.9.1 Chromium Data Set

The Study Area chromium data set consists of 1,536 surface and 1,530 subsurface samples. The Upriver data set consists of 66 surface and 3 subsurface samples, the downtown data set consists of 265 samples and 178 subsurface samples, and the downstream data consists of 25 surface and 26 subsurface samples.

5.2.9.2 Chromium in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Chromium was reported in all 66 surface sediment samples within the Upriver reach, reported concentrations ranged from 12J to 41 mg/kg (Table 5.2-11), all results were between 10 and 100 mg/kg with a mean of 23 mg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

Chromium was reported in all 265 surface sediment samples within the Downtown reach. Concentrations reported ranged from 1.2J to 758 J mg/kg (Table 5.2-15a), with a mean concentration of 35 mg/kg. The majority of the results are less than 50 mg/kg, with concentrations greater than 50 mg/kg present at RM 13 on the eastern shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges (Map 5.2-46).

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Within the Downtown reach, 14 results (5 percent of data set) were reported at concentrations greater than 100 mg/kg, 218 results (82 percent) were between 10 and 100 mg/kg, and 33 results (12 percent) were reported at concentrations less than 10 mg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Chromium was reported in 110 surface sediment samples within the Zidell action area with concentrations ranging from 1.24J mg/kg to 758J mg/kg (Table 5.2-15c), with a mean of 56 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of chromium concentrations in surface sediment is from 4.5 mg/kg to 189 mg/kg with a mean concentration of 19 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Chromium was reported in 1,530 of 1,536 surface sediment samples within the Study Area (detection frequency of 99.6 percent). Reported concentrations ranged from 4.1J to 819J mg/kg (Table 5.2-1), with a mean of 35 mg/kg.

Concentrations greater than 100 mg/kg are present in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4.4, RM 5.6-5.9, and in Swan Island Lagoon (Figure 5.2-341 and Map 5.2-27), single results greater than 100 mg/kg are present at RM 7.2 and RM 11. The maximum reported concentration in the eastern nearshore zone (819J mg/kg) was found at Station RB06 at RM 2.2. Mean concentrations (Table 5.2-3) in these areas in the eastern nearshore zone are 100 mg/kg at RM 1.9-3, 31 mg/kg at RM 3-4; 29 mg/kg at RM 4-5, 45 mg/kg at RM 5-6, 35 mg/kg at RM 7-8, 35 mg/kg in Swan Island Lagoon, and 38 mg/kg at RM 11-11.8.

Reported concentrations in the western nearshore zone greater than 100 mg/kg are located at RM 6-6.1, RM 6.8-6.9, and RM 8.8-9.2 (Figure 5.2-341). The maximum reported concentration of chromium in surface sediment of 774 mg/kg was found at Station 19A01 (RM 8.4W). Mean concentrations in these areas are 39 mg/kg at RM 6-7, 35 mg/kg at RM 7-8, 47 mg/kg at RM 8-9, and 39 mg/kg at RM 9-10 (Table 5.2-7). All chromium results from the navigation channel were less than 100 mg/kg.

Thirty-nine results were reported at concentrations greater than 100 mg/kg, 1,466 results (96 percent) were reported at concentrations between 10 and 100 mg/kg, and the remaining 25 results were reported at concentrations less than 10 mg/kg (Table 5.2-9).

~~Chromium concentrations were relatively low (<50 mg/kg) throughout the majority of the Study Area (Maps 5.1-21 and 5.1-22a–m, see frequency plot inset), including the navigation channel. Detection frequencies were nearly 100 percent for both surface and~~

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~~subsurface samples (Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were below 55.8 V mg/kg.~~

~~Clusters of chromium concentrations greater than 50 mg/kg were identified in several areas along the eastern and western shorelines (Maps 5.1-21 and 5.1-22a–m; Figures 5.1-25 and 5.1-26). The maximum chromium surface concentration was found at Station RB06 in the RM 2.2 vicinity.~~

Downstream Reach (RM 0 to 1.9)

Chromium was reported in all 25 surface sediment samples within the Downstream reach. Reported concentrations range from 10J to 42 mg/kg (Tables 5.2-19 and 5.2-21), with a mean concentration of 25 mg/kg.

5.2.9.3 Chromium in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Chromium concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 20 mg/kg to 23 mg/kg; the average concentration for this reach is 21 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Chromium was reported in 174 of 178 subsurface sediment samples within the Downtown reach. Concentrations reported ranged from 4.6 to 143 mg/kg (Table 5.2-16a), with a mean of 22 mg/kg. Table 5.2-17 shows that only one result was reported at a concentration greater than 100 mg/kg, 161 results (93 percent of reported results) were reported at concentrations between 1 and 10 mg/kg, 12 results were reported at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Data statistics for the Downtown reach excluding the Zidell data are presented in Table 5.2-16b presents, and Table 5.2-16c presents statistics with the Zidell data removed from the Downtown data set. Chromium was reported in 30 subsurface sediment samples within the Zidell action area, concentrations reported ranged from 14 to 143 mg/kg, with a mean of 36 mg/kg. When data from the Zidell facility are excluded from the downtown data set, reported chromium concentrations in subsurface sediment ranged from 4.6 to 72 mg/kg, with a mean of 19 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Chromium was reported in 1,524 of 1,530 subsurface samples. Reported concentrations ranged from 6.4J to 484 mg/kg (Table 5.2-2), with a mean of 29 mg/kg. The distribution of reported chromium concentrations in subsurface sediment within the Study Area is shown on Figure 5.2-3~~4~~2.

Concentrations greater than 100 mg/kg were observed within the eastern nearshore zone at RM 2.2-2.4, RM 5-6 and in Swan Island Lagoon (~~Figure 5.2-26,~~ Figure 5.2-3~~4~~2 and

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Map 5.2-28a-o). The highest reported subsurface concentration in the eastern nearshore zone (249 mg/kg) was found at Station C207-1 near RM 5.6. Mean concentrations in these areas are 30.5 mg/kg at RM 1.9-3, 56 mg/kg at RM 5-6, and 31 mg/kg in Swan Island Lagoon (Table 5.2-3).

Reported chromium concentrations greater than 100 mg/kg are present in the western nearshore zone at RM 6.1, RM 7.4 and RM 8.8-9.2 (Figure 5.2-328). The maximum subsurface concentration (484 mg/kg) was found at Station HA-42 (46–61 cm bml) at RM 8.9. Mean concentrations in these areas are 30.3 mg/kg at RM 6-7, 32.3 mg/kg at RM 7-8; 35.2 mg/kg for RM 8 to 9; and 60.5 mg/kg for RM 9 to 10. (Table 5.2-8)

Within the navigation channel, chromium greater than 100 mg/kg was reported at RM 6.4 and 11.3. Mean concentrations for these areas are 22.9 mg/kg at RM 6-7and 21.5 mg/kg at RM 11-11.8 (Table 5.2-6).

Fourteen results were reported at concentrations greater than 100 mg/kg, 1,452 results were between 10 and 100 mg/kg, and 58 results are comprised of concentrations less than 10 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

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Chromium was reported in all 26 subsurface sediment samples collected within the Downstream reach. Concentrations reported ranged from 6.6 to 34 mg/kg (Tables 5.2-20 and 5.2-21), with a mean of 23 mg/kg.

5.2.9.4 Chromium Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination.

Within the downtown reach, chromium concentrations are greater in surface sediment than in subsurface sediment, the mean surface concentration is 35 mg/kg, while the mean subsurface sediment concentration is 22 mg/kg (Tables 5.2-15a and 5.2-16a).

Within the Study Area, chromium concentrations are also generally greater in the surface sediments than in subsurface sediments as a whole. Mean concentrations are 35 mg/kg in surface and 29 mg/kg subsurface sediment (Tables 5.2-1 and 5.2-2, Figure 5.2-343). Mean concentrations are greater in the nearshore areas than in the navigation channel.

Within the eastern nearshore zone, concentrations surface sediment are greater than in subsurface sediment in all river mile except RM 5-7 and RM 8-9. Within the western nearshore zone, chromium concentrations in subsurface sediment concentrations are

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greater than in surface sediment in all river miles except RM 9-10 and RM 11-11.8. Within the navigation channel, surface and subsurface sediment concentrations are generally comparable. The highest concentrations of chromium in subsurface sediment align with areas where surface sediment concentrations are greatest.

Within the downstream reach, concentrations in surface sediment are generally greater than in subsurface sediment. The mean surface concentration is 25 mg/kg, while the mean subsurface concentration is 23 mg/kg (Tables 5.2-19 and 5.2-20)

~~5.13.87.19~~5.2.10 Copper in Sediment

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The distribution of copper concentrations throughout the Study Area is depicted on Map 5.2-29, reported concentrations with depth at subsurface stations are depicted on Maps 5.2-30a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps, all subsurface samples are presented. Scatter plots of the copper data set for surface and subsurface sediment in the Study Area are presented on Figures 5.2-34~~45~~ and 5.2-35~~46~~, respectively, segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

Summary statistics for copper in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Reported copper concentrations as orders of magnitude are presented in Table 5.2-9 (detected results only) and Table 5.2-10 (combined detect and nondetect results). Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-36~~47~~.

Data for the Upriver, Downtown, and Downstream reaches are only presented in statistical tables and order of magnitude tables. Additionally, surface sediment data for the Downtown reach are presented in Map 5.2-47. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12, number of results by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16, number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect).

5.2.10.1 Copper Data Set

Copper data for the Study Area data consists of 1,552 surface and 1,541 subsurface samples. The Upriver data set includes 72 surface and 3 subsurface samples, the

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downtown data set consists of 269 surface and 178 subsurface samples, and the downstream data set consists of 25 surface samples and 26 subsurface samples.

5.2.10.2 Copper in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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Copper was reported in all 72 surface sediment samples within the Upriver reach. Concentrations reported with detected concentrations ranged from 11J m to 51 mg/kg, with a mean of 25 mg/kg (Table 5.2-11). All detected values were between 10 and 100 mg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

Copper was reported in 264 of 269 surface sediment samples within the Downtown reach. Concentrations reported ranged from 5.5 to 2,150J mg/kg with a mean of 99 mg/kg (Table 5.2-15a). The distribution of copper concentrations in surface sediment within the Downtown reach is presented on Map 5.2-47. Reported concentrations are generally less than 300 mg/kg, although areas with concentrations greater than 600 mg/kg are noted at RM 13 on the western shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

Within the Downtown reach, seven results were reported at concentrations greater than 1,000 mg/kg, 29 were reported at concentrations between 100 and 1,000 mg/kg, 222 results (84 percent) were reported at concentrations between 10 and 100 mg/kg, and 2 results were reported at concentrations less than 10 mg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Copper was reported in 110 surface sediment samples within the Zidell action area, reported concentrations ranged from 5.51 to 2,150J mg/kg (Table 5.2-15c), with a mean of 195 mg/kg. When the data for the Zidell facility is excluded from the downtown data set, reported copper concentrations in surface sediment range from 8.4 to 366 mg/kg, with a mean of 33 mg/kg (Table 5.2-15b).

Study Area Reach (RM 1.9 to 11.8)

Copper was reported in 1,548 of 1,552 surface sediment samples. Concentrations reported ranged from 6.2J to 2,830 mg/kg), with a mean of 61 mg/kg (Table 5.2-1). The distribution of concentrations in surface sediment is presented on Figure 5.2-3445.

Copper in surface sediment at concentrations greater than 100 mg/kg in surface sediment in the eastern nearshore zone are present at RM 2.1-2.4, RM 3.7-4, RM 5.5-6.1, Swan Island Lagoon, and RM 11.1-11.3 (Figure 5.2-3445 and Map 5.2-29). Single results greater than 100 mg/kg are present at RM 6.6, RM 7.2 and RM 9.9. ~~Copper data~~

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~~showed concentrations greater than 60 mg/kg (Maps 5.1-23 and 5.1-24a–m, see frequency plot inset) at many locations along the eastern and western nearshore zones, but few in the navigation channel. Detection frequencies were nearly 100 percent for both surface and subsurface samples (Figures 5.1-27 and 5.1-28; Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were below 172 V mg/kg.~~

~~As shown in Maps 5.1-23 and 5.1-24a–m, copper was greater than 60 mg/kg in isolated groupings at several locations along the eastern and western shorelines. A surface sample at RM 11.2 (Station UG01) contained the highest concentration of copper.~~ Mean concentrations (Table 5.2-3) in these areas are 42 mg/kg at RM 1.9-3, 38 mg/kg at RM 3-4, 135 mg/kg at RM 5-6, 53.5 mg/kg at RM 6-7, 53 mg/kg at RM 7-8, 122 mg/kg in Swan Island Lagoon; 31.6 mg/kg at RM 9-10, and 161 mg/kg at RM 11-11.8. The highest reported concentration of 2,830 mg/kg copper was reported at RM 11.2E (Station UG01)

Areas where copper concentrations are reported greater than 100 mg/kg in the western nearshore zone are present from RM 4.3 through 10.4, and in particular at RM 4.3-4.7, RM 5.6-6.1, RM 6.8-7.4, RM 8.3-9.2, and RM 10.2-10.4 (Figure 5.2-34~~45~~). The maximum reported concentration in the western nearshore zone of 1,370 mg/kg was found at Station HA-43 (RM 9.2W). Mean concentrations in these areas are 39.8 mg/kg at RM 4-5, 50.7 mg/kg at RM 5-6, 46.9 mg/kg at RM 6-7, 41.4 mg/kg at RM 7-8, 102 mg/kg at RM 8-9, 110 mg/kg at RM 9-10, and 164 mg/kg at RM 10-11 (Table 5.2-7).

Within the navigation channel, the highest reported copper concentrations are located at RM 5, RM 7.9, and RM 10.3-10.4. Reported concentrations at RM 5 and 7.9 appears to be associated with results observed in the eastern nearshore area, while the results RM 10.3-10.4 appear to be associated with observed concentrations in the western nearshore area (Map 5.2-29). The mean concentrations for these areas are 30.1 mg/kg at RM 5-6, 49.3 mg/kg at RM 7-8, 62 mg/kg in Swan Island Lagoon, and 39.7 mg/kg at RM 10-11 (Table 5.2-5).

Within the Study Area, copper was reported at concentrations greater than 1,000 mg/kg in four results, 144 results were greater than 100 mg/kg, 1,392 results (90 percent of the detected results) were reported at concentrations between 10 and 100 mg/kg, and eight results were reported at concentrations less than 10 mg/kg. Downstream Reach (RM 0 to 1.9) Table 5.2-9

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Copper was reported in all 25 surface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 8 mg/kg to 46 mg/kg (Table 5.2-19). Table 5.2-21 shows that 23 samples are measured at concentrations between 10 and 100 mg/kg and two samples are measured at concentration between 1 and 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg. The mean copper concentration in this reach is 26 mg/kg.

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5.2.10.3 Copper in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Only three subsurface sediment samples were analyzed for copper in the Upriver reach, all between RM 15.4 and 16. Reported concentrations range from 26 to 33 mg/kg, with a mean of 29 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Copper was reported in all 178 subsurface sediment samples within the Downtown reach. Concentrations reported range from 9.5 to 1,050 mg/kg with a mean of 46 mg/kg (Table 5.2-16a). One result was reported at a concentration greater than 1,000 mg/kg, eight were reported at concentrations between 100 and 1,000 mg/kg, 167 results were reported at concentrations between 10 and 100 mg/kg, and two results were reported at concentrations less than 10 mg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Summary statistics for the Downtown reach excluding the Zidell data are presented in Table 5.2-16b and Table 5.2-16c presents statistics for the Zidell data. Copper was reported in 30 subsurface sediment samples within the Zidell action area. Concentrations reported range from 14 to 1,050 mg/kg, with a mean of 42 mg/kg. Excluding the data from the Zidell site, reported concentrations range from 9.5 to 457 mg/kg, with a mean of 39 mg/kg (Table 5.2-16c).

Study Area Reach (RM 1.9 to 11.8)

Within the Study Area, copper was reported in 1,548 of 1,552 subsurface samples. Concentrations reported range from 9.4J mg/kg to 3,290 mg/kg, with a mean of 55 mg/kg (Table 5.2-2). The distribution of concentrations in subsurface sediments is presented on Figure 5.2-3546 and Maps 5.2-30a-o.

The subsurface sediment has elevated concentrations in generally the same areas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-3546). The maximum subsurface copper concentration (3,290 mg/kg) was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon. Concentrations greater than 100 mg/kg are noted at RM 3.6, RM 4.4-4.6, RM 5.6, RM 6.1-6.7, RM 7.4, in Swan Island Lagoon, RM 8.4-8.8, and RM 11.3 (Figure 5.2-3546 and Map 5.2-30a-o). ~~The maximum subsurface copper concentration was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon.~~ Mean copper concentrations in these areas in the eastern nearshore zone are 35.6 mg/kg at RM 3-4, 30.2 mg/kg at RM 4-5, 56.9 mg/kg at RM 5-6, 70 mg/kg at RM 6-7, 48.3 mg/kg at RM 7-8, 128 mg/kg at RM 8-9, and 145 mg/kg in Swan Island Lagoon (Table 5.2-3).

Within the western nearshore zone, copper concentrations exceeding 100 mg/kg are present from RM 4.1 through 9.2, at RM 4.8-4.9 and RM 8.3-9.2 (Figure 5.2-3546 and Map 5.2-30a-o). The maximum reported subsurface concentration of 1,990 mg/kg in the western nearshore zone was found at Station HA-42 (46–61 cm bml) at RM 8.9. Mean

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concentrations in these areas are 48 mg/kg at RM 4-5, 33.9 mg/kg at RM 5-6, 39.4 mg/kg at RM 6-7, 42.6 mg/kg at RM 7-8, 59.8 mg/kg at RM 8 to 9, and 229 mg/kg at RM 9-10 (Table 5.2-8)

There are two are with results greater than 100 mg/kg in the navigation channel, located at RM 7.6-8 and RM 10.2-10.3. The results at RM 7.6-8 appear associated with concentrations observed in the eastern nearshore zone, and the results at RM 10.2-10.3 appear co-located with elevated concentrations the western nearshore zone. The mean concentrations for these areas are 68.7 mg/kg at RM 7-8, and 51.4 mg/kg at RM 10-11 (Table 5.2-6).

Table 5.2-9 shows that there are a~~A~~ total of six results in subsurface sediment were ported at concentrations greater than 1,000 mg/kg, 78 results were between 100 and 1,000 mg/kg, 1,456 results were reported at concentrations between 10 and 100 mg/kg, and one result was than 10 mg/kg.

Downstream Reach (RM 0 to 1.9)

Copper was reported in all 26 subsurface sediment samples within the Downstream reach. Concentrations reported range from 8.9 to 44 mg/kg, with a mean of 26 mg/kg (Table 5.2-20). Table 5.2-21 shows that the majority of samples (a total of 24 of the 26 results) were reported at a concentration greater than 10 mg/kg, two samples were reported at a concentration less than 10 mg/kg.

5.2.10.4 Copper Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination.

The mean surface sediment concentrations of 99 mg/kg in the downtown reach is greater than the subsurface mean of 46 mg/kg (Tables 5.2-15a). However, when the Zidell data is excluded, the mean surface and subsurface sediment concentrations are similar (33 mg/kg and 39 mg/kg, respectively, Table 5.2-15b).

Copper concentrations are generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean surface sediment concentration is 61 mg/kg and the mean subsurface sediment concentration is 55 mg/kg (Tables 5.2-1 and 5.2-2). Mean concentrations are greater in the nearshore areas than in the navigation channel, and the mean concentration in the eastern nearshore zone is greater concentrations than in the western nearshore zone. Mean concentrations are comparable in surface and subsurface sediment (Figure 5.2-36~~47~~).

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In the eastern nearshore zone, mean concentrations in surface sediment are greater than in subsurface sediment in all river mile zones except RM 6-7, RM 8-9, and in Swan Island Lagoon. In the western nearshore zone, mean concentrations in subsurface sediment are greater than in surface sediment in all river miles except RM 5-7 and RM 8-9. Within the navigation channel, mean subsurface and surface sediment concentrations are comparable, with the mean subsurface sediment concentrations slightly greater in all river miles except RM 1.9-3 and RM 4-7.

Areas with the highest copper concentrations in subsurface sediment align with the locations where surface sediment concentrations are greatest, although there are more areas with elevated surface or subsurface sediment concentrations (Figure 5.2-3647). Mean surface and subsurface concentrations in the downstream reach are both 26 mg/kg (Tables 5.2-19 and 5.2-20).

~~5.13.87.20~~5.2.11 Zinc in Sediment

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The distribution of zinc concentrations throughout the Study Area is presented on Map 5.2-31, reported concentrations with depth are depicted on Maps 5.2-32a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two results is presented, all subsurface results are presented. Scatter plots of zinc results in the Study Area are presented on Figures 5.2-3749 and 5.2-3850 for surface and subsurface sediment, respectively, segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

Summary statistics are presented in Tables 5.2-1 and 5.2-2 for surface and subsurface sediment, respectively, within the Study Area, and in Tables 5.2-3 and 5.2-4 for the eastern nearshore zone, Table 5.2-5 and 5.2-6 for the navigation channel, and Tables 5.2-7 and 5.2-8 for the western nearshore zone. Results by order of magnitude (<1, 1-10, 10-100, 100-1,000) are presented in Tables 5.2-9for detected results only and Table 5.2-10 for combined detected and nondetect values. Finally, a histogram presenting average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-3951.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables, the Downtown reach surface sediment results are also presented in Map 5.2-48. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12, respectively. The number of results by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics of results within the Downtown reach are shown in Tables 5.2-15 and 5.2-16 for surface and subsurface sediment, respectively. The number of results by order of magnitude are provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics of results within the Downstream reach are shown in Tables 5.2-19 and 5.2-20 for surface and subsurface sediment, respectively. The number of results by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and

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nondetects). ~~Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-52.~~

5.2.11.1 Zinc Data Set

The zinc data set Study Area consists of 1,581 surface and 1,581 subsurface samples. 72 surface and 3 subsurface samples from the Upriver reach, 269 surface and 178 subsurface samples from the downtown reach, and 25 surface and 26 subsurface samples downstream reach.

5.2.11.2 Zinc in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Zinc was reported in all 72 surface sediment samples within the Upriver reach. Concentrations reported range from 41J to 165 mg/kg, with a mean of 75 mg/kg (Table 5.2-11) (Table 5.2-13 Four results were reported at concentrations greater than 100 mg/kg, the remaining 68 data points were between 10 and 100 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Zinc was reported in all 269 surface sediment samples within the Downtown reach. Concentrations reported range from 3.3J to 6,480J mg/kg, with a mean of 294 mg/kg (Table 5.2-15a). The distribution of surface sediment results in the Downtown reach is presented on Map 5.2-48. The majority of results are less than 300 mg/kg, concentrations greater than 600 mg/kg were reported at RM 13 on the western shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

Concentrations greater than 1,000 mg/kg were reported in 15 results, 102 results were reported at concentrations between 100 to 1,000 mg/kg, 151 results were reported at concentrations between 10 and 100 mg/kg, one result was reported at a concentration less than 10 mg/kg (Table 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Summary statistics for the Downtown reach are presented in Table 5.2-15b excluding the Zidell data, and the Zidell data are presented in Table 5.2-15c. Zinc was reported in all110 surface sediment samples within the Zidell action area, concentrations reported range from 3.27J to 6,480J mg/kg, with a mean of 555 mg/kg (Table 5.2-15c). With the Zidell facility excluded from the downtown data set, reported zinc concentrations range from 23 to 1,450 mg/kg, with a mean of 113 mg/kg (Table 5.2-15b).

Study Area Reach (RM 1.9 to 11.8)

Zinc was reported in all 1,581 surface sediment samples within the Study Area. Concentrations reported range from 3.7J to 4,220 mg/kg, with a mean of154 mg/kg

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(Table 5.2-1). The distribution of reported zinc concentrations within the Study Area is shown on Figure 5.2-37~~49~~.

Concentrations greater than 300 mg/kg were reported in the eastern nearshore zone at RM 2.1-2.3, RM 3.7-4.6, RM 5.6-5.9, and in Swan Island Lagoon (Figure 5.2-37~~45~~ and Map 5.2-29). Single exceedances greater than 300 mg/kg were reported at RM 6.7, RM 7.2, RM 9.9, and RM 11.3. The highest zinc concentration in the eastern nearshore zone of 2,050 mg/kg was reported at RM 4.6 (Station T4-UP13). Mean zinc concentrations in these areas in the eastern nearshore zone are 190 mg/kg at RM 1.9-3 159 mg/kg at RM 3-4, 234 mg/kg at RM 4-5, 192 mg/kg RM 5-6, 123 mg/kg at RM 6-7, 114 mg/kg at RM 7-8, 227 mg/kg in Swan Island Lagoon, 97.1 mg/kg at RM 9-10, and 132 mg/kg at RM 11-11.8 (Table 5.2-3).

Concentrations greater than 300 mg/kg were reported in the western nearshore zone from at RM 6.1, RM 6.7-6.8, RM 8.1-9.3, RM 9.6-9.7, and RM 10.3-10.4 (Figure 5.2-37~~49~~). The maximum reported concentration of zinc in surface sediment in the Study Area of 4,220 mg/kg was detected at Station HA-43 at RM 9.2W. Mean concentrations for these areas are 150 mg/kg at RM 6-7, 290 mg/kg at RM 8-9, 394 mg/kg at RM 9-10, and 212 mg/kg at RM 10-11 (Table 5.2-7). All reported concentrations of zinc in the navigation channel were less than 300 mg/kg.

Within the Study Area, zinc was reported at concentrations greater than 1,000 mg/kg in 15 results, 914 were reported at concentrations greater than 100 mg/kg, 650 results were reported at concentrations between 10 and 100 mg/kg, and two results were reported at concentrations less than 10 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Zinc was reported in all 25 surface sediment samples within the Downstream reach, concentrations reported ranged from 48 to 188 mg/kg, with a mean of 98 mg/kg (Table 5.2-19). Concentrations greater than 100 mg/kg were reported in 12 results, 13 results were reported at concentrations between 10 and 100 mg/kg (Table 5.2-21).

5.2.11.3 Zinc in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Zinc was analyzed in only three subsurface samples between RM 15.4 and 16 and reported at concentrations ranging from 66 mg/kg to 119 mg/kg, with a mean of 88 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Zinc was reported in all 178 subsurface sediment samples from within the Downtown reach. Concentrations reported ranged from 21 to 11,100J mg/kg, with a mean of 379 mg/kg (Table 5.2-16a). One result was reported at a concentration greater than 10,000 mg/kg, nine results were reported at concentrations between 1,000 and 10,000 mg/kg,

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77 results were reported at concentrations between 100 and 1,000 mg/kg, and 91 results were reported at concentrations between 10 and 100 mg/kg (Table 5.2-17).

Summary statistics for the Downtown reach are presented in Table 5.2-16b with the Zidell data excluded, and the Zidell data are summarized in Table 5.2-16c. Zinc was reported in 30 samples within the Zidell action area at concentrations ranging from 41 to 2,270 mg/kg, with a mean of 207 mg/kg. With the Zidell data excluded from the downtown data, reported zinc concentrations in subsurface sediment range from 21 to 11,100J mg/kg, with a of 414 mg/kg (Table 5.2-16c),

Study Area Reach (RM 1.9 to 11.8)

Zinc was analyzed and detected in 1,581 samples within the Study Area (100 percent detection frequency) with concentrations ranging from 24 mg/kg to 9,000 mg/kg (Table 5.2-2) and a mean concentration of 147 mg/kg. Similar to surface sediment, zinc concentrations in the subsurface also varied within the Study Area (Figure 5.2-38~~50~~; Maps 5.2-32a-o).

The subsurface sediment has elevated concentrations in generally the same areas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-38~~50~~). Concentrations greater than 300 mg/kg are noted at RM 2.3, 3.7, RM 4.2-4.6, RM 5.6, RM 6.7, in Swan Island Lagoon, RM 8.4-8.6, and RM 11.1 (Figure 5.2-39~~51~~ and Map 5.2-32a-o). The maximum subsurface zinc concentration in the eastern nearshore zone (1,930 mg/kg) was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon. Mean zinc concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 131 mg/kg for RM 1.9 to 3; 149 mg/kg for RM 3 to 4; 155 mg/kg for RM 4 to 5; 171 mg/kg for RM 5 to 6; 133 mg/kg for RM 6 to 7; 291 mg/kg for RM 8 to 9; 181 mg/kg in Swan Island Lagoon, and 159 mg/kg for RM 11 to 11.8.

The western nearshore zone has detected zinc concentrations that exceed 300 mg/kg from RM 6.7 through 9.2 with clusters noted at RM 6.7, RM 7.6-7.7, and RM 8.3-9.2 (Figure 5.2-38~~50~~ and Map 5.2-32a-o). The maximum subsurface concentration (9,000 mg/kg) was found at Station HA-42 (~~46~~–61 cm bml) at RM 8.9. Mean concentrations (Table 5.2-8) for these areas in the western nearshore zone are: 126 mg/kg for RM 6 to 7; 131 mg/kg for RM 7 to 8; 190 mg/kg for RM 8 to 9; and 792 mg/kg for RM 9 to 10.

There is one peak with samples greater than 300 mg/kg in the navigation channel zone located at RM 10.2-10.3 with two individual samples exceeding 300 mg/kg at RM 6.4 and RM 7.9. The concentrations elevated within the navigation channel are near elevated concentrations the western nearshore zone. The mean concentrations for these areas are: 102 mg/kg for RM 6 to 7; 125 mg/kg for RM 7 to 8; and 127 mg/kg for RM 10 to 11 (Table 5.2-6).

Table 5.2-9 shows that there are 6 subsurface samples greater than 1,000 mg/kg and 834 samples ranging between 100 and 1,000 mg/kg. Subsurface sediment values greater than 100 mg/kg accounts for 53 percent of the detected data set. The remainder of the

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detected data set (741 samples; 47 percent) is between 10 and 100 mg/kg. There were no samples detected at concentrations less than 10 mg/kg.

Downstream Reach (RM 0 to 1.9)

Zinc was analyzed and detected in 26 subsurface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 11 mg/kg to 244 mg/kg (Table 5.2-20). Table 5.2-21 shows that approximately half of samples (14 samples) were detected at a concentration greater than 100 mg/kg and half the samples (12 samples) were detected at a concentration less than 100 mg/kg. There were no samples were detected at concentrations less than 10 mg/kg. The mean zinc concentration in this reach is 118 mg/kg.

5.2.11.4 Zinc Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean zinc surface sediment concentration in this reach is 75 mg/kg (Table 5.2-11).

The surface sediment concentrations in the downtown reach were lower than the subsurface concentrations. The mean surface concentration is 294 mg/kg, while the mean subsurface sediment concentration is 379 mg/kg (Tables 5.2-15a and 5.2-16a).

Zinc concentrations are generally greater in the surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 154 mg/kg and the mean subsurface sediment concentration is 147 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-39~~51~~ shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the western nearshore zone has slightly greater subsurface concentrations than the eastern nearshore zone while the eastern nearshore zone has higher surface concentration. It also shows that concentrations are generally about the same in the surface sediment and subsurface sediment.

In the eastern nearshore zone, surface sediment is greater than subsurface sediment in all river mile zones except RM 6 to 9 and RM 10 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles excpt RM 3 to 4, RM 6 to 7 and RM 8 to 9. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations, although the subsurface sediment concentrations are slightly greater in all river miles except RM 5 to 6.

Areas where subsurface sediment concentrations are elevated generally align with the locations where surface sediment concentrations are elevated, although there are more

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areas with elevated subsurface sediment concentrations. The most prominent areas are RM 4 to 5, in Swan Island Lagoon, and RM 8 to 9 in the eastern nearshore zone, and RM 8 to 10 in the western nearshore zones. Additional areas with elevated concentrations are RM 1.9 to 3 and RM 5 to 6 in the eastern nearshore zone, and RM 10 to 11 in the western nearshore zone (Figure 5.2-39~~51~~).

The subsurface sediment concentrations in the downstream reach were greater than surface concentrations. The mean surface concentration is 98 mg/kg, while the mean subsurface concentration is 118 mg/kg (Tables 5.2-19 and 5.2-20)

~~5.13.87.21~~5.2.12 Tributyltin Ion in Sediment

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Several data presentations for the surface and subsurface tributyltin ion data sets for the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface sediment concentrations by river mile. The distribution of tributyltin ion concentrations at each surface sampling station throughout the Study Area is depicted in Map 5.2-33, concentrations with depth at subsurface stations are depicted in Maps 5.2-34a–o.

The data for tributyltin ion in the study area is presented on scatter plots on Figures 5.2-40~~53~~ and 5.2-41~~54~~ for surface and subsurface sediment, respectively. These plots present the data in three panels segregated by the eastern nearshore, navigation channel, and western nearshore zones (Map 5.2-33).

Summary statistics tributyltin ion within the Study Area are shown in Tables 5.2-1 and 5.2-2 for surface and subsurface sediment, respectively. Summary statistics for surface and subsurface sediment and are presented in Tables 5.2-3 and 5.2-4 within the eastern nearshore, Tables 5.2-5 and 5.2-6 in the navigation channel, and Tables 5.2-7 and 5.2-8 for the western nearshore zones. Tributyltin ion data is presented as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) in Table 5.2-9 for detected values, and Table 5.2-10 for combined detect and nondetect values. Finally a histogram presenting the average surface and subsurface sediment values for tributyltin ion by river mile and for the entire Study Area is presented in Figure 5.2-42~~59~~.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, surface sediment results for the Downtown reach are presented on Map 5.2-49. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12, number of results by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and nondetects). Summary statistics for surface and subsurface sediment within the Downtown reach are presented in Tables 5.2-15 and 5.2-16, number of results by order of magnitude are provided in tables 5.2-17 (detects only) and 5.2-18 (detects and nondetects). Summary statistics for surface and subsurface sediment with the Downstream reach are presented in Tables 5.2-19 and

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5.2-20, number of results by order of magnitude are provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and nondetects).

5.2.12.1 Tributyltin Ion Data Set

Sampling for tributyltin ion analysis was based on a biased approach at locations near known or suspected sources. As a result, there are relatively fewer data points for these analytes in the RI sediment database than for other chemicals. This is particularly true in areas away from suspected sources, such as the navigation channel.

The existing tributyltin ion data are sufficient for RI purposes; however, as will be pointed out in this section and later in Section 10, the fewer number of data points for tributyltin ion in some areas limits the level of detail to which the extent of chemical distribution may be resolved, and introduces the need for caution in interpreting the surface to subsurface trends shown by the histograms (Figures 5.2-42~~59~~) and in making conclusions regarding the spatial patterns of the composition of tributyltin ion in sediment (Sections 5.2.13.2 and 5.2.13.3). Within the Study Area, tributyltin ion was analyzed in 358 surface and 433 subsurface samples. The Upriver data set consists of 8 surface and 3 subsurface samples. The downtown data set is 174 surface and 65 subsurface samples, and the downstream data set is 4 surface and no subsurface samples.

5.2.12.2 Tributyltin Ion in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Tributyltin ion was reported in 4 of 8 surface sediment samples within the Upriver reach, concentrations reported range from 0.72J to 2.3 µg/kg (Table 5.2-11). Three results were reported at concentrations between 1 and 10 µg/kg, and one result was reported at a concentration less than 1 µg/kg. The mean concentration in this reach is 1.3 µg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

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Tributyltin ion was reported in 62 of 174 surface sediment samples within the Downtown reach (frequency of detection 36 percent). Concentrations ranging from 0.4J to 1,990 µg/kg, with a concentration of 75 µg/kg (Table 5.2-15a). Results with the highest concentrations are located along the western shoreline (Map 5.2-49).

Tables 5.2-17 shows that there are Two results were reported at concentrations greater than 1,000 µg/kg, two between 100 and 1,000 µg/kg, 12 results were reported at concentrations between 10 and 100 µg/kg, 32 results between 1 and 10 µg/kg, and14 results were reported at concentrations less than 1 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Summary statistics for the Downtown reach excluding the Zidell data are presented in Table 5.2-15b, and summary statistics for the Zidell data excluded from the Downtown

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data set are presented in Table 5.2-15c. Tributyltin ion was reported in 26 of 80 surface sediment samples within the Zidell action area, concentrations reported range from 1.9 to 1,990 µg/kg, with a mean of 102 µg/kg (Table 5.2-15c). With the Zidell data excluded from the downtown data set, reported tributyltin concentrations range from 0.4J to 1,700 J µg/kg, with a mean of 55 µg/kg (Table 5.2-15b),

Study Area Reach (RM 1.9 to 11.8)

Tributyltin ion was reported in 333 of 358 surface sediment samples within the Study Area. Concentrations reported range from 0.45J to 47,000 µg/kg with a mean of 466 µg/kg (Table 5.2-1). The distribution of reported tributyltin ion concentrations within the Study Area is presented on Figure 5.2-4049 and Map 5.2-33.

Concentrations greater than 1,000 µg/kg in the eastern nearshore zone were reported at RM 3.7 and in Swan Island Lagoon. The highest reported surface sediment concentration of 47,000 µg/kg was reported at Station SD12 (RM 3.7, at the head of International Slip), a concentration of 46,000 µg/kg was reported at Station G421 in Swan Island Lagoon. Mean concentrations in these areas are 1,570 µg/kg at RM 3-4, and 2,340 µg/kg in Swan Island Lagoon (Table 5.2-3).

Within the navigation channel, tributyltin ion concentrations greater than 1,000 µg/kg were reported near Swan Island Lagoon (1,800 µg/kg at Station SD124 at RM 7.7, Figure 5.2-409). The mean concentration at RM 7-8 in this areas is 373 µg/kg (Table 5.2-5).

A single measurement greater than 1,000 µg/kg was reported at RM 8.8 in the western nearshore zone, the mean concentration at RM 8-9 is 84 µg/kg (Table 5.2-7).

Two results were reported at concentrations greater than 10,000 µg/kg, 12 results were between 1,000 and 10,000 µg/kg, 71 results were reported at concentrations between 100 and 1,000 µg/kg, 125 results were between 10 to 100 µg/kg, 108 results between 1 and 10 µg/kg, and 15 results were reported at concentrations less than 1 µg/kg (Tables 5.2-9, Map 5.2-33)

Downstream Reach (RM 0 to 1.9)

Tributyltin ion was reported in all 4 samples within the Downstream reach at concentrations between from 0.37J and 1.2J µg/kg, with a mean of 0.85 µg/kg (Tables 5.2-19,5.2-21 and 5.2-22).

5.2.12.3 Tributyltin Ion in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Tributyltin ion was analyzed in three subsurface sediment samples between RM 15.4 and 16, and was not detected at maximum detection limit of 0.094 µg/kg.

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Downtown Reach (RM 11.8 to 15.3)

Tributyltin ion was reported in 21 of 65 subsurface sediment samples within the Downtown reach, concentrations reported range from 0.55 J µg/kg to 14,000 µg/kg (Table 5.2-15a) and a mean concentration of 1,052 µg/kg.

One result was reported at a concentration greater than 10,000 µg/kg, one each was reported between 1,000 and 10,000 µg/kg and between 100 and 1,000 µg/kg, five results were between 10 and 100 µg/kg, nine were between 1 and 10 µg/kg, and four results were reported at a concentration less than 1 µg/kg (Tables 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Summary statistics for the Downtown reach with the Zidell data excluded are presented in Table 5.2-16b, and summary statistics for the Zidell data are presented in Table 5.2-16c. Tributyltin ion was reported in 23 subsurface sediment samples within the Zidell action area, concentrations reported range to a maximum reported value of 14,000 µg/kg, with a mean of 1,697 µg/kg. When the data from the Zidell facility are excluded from the downtown data set, the range of reported concentrations ranges from 0.55J to 23 µg/kg, with a mean of 4.5 µg/kg (Table 5.2-16c).

Study Area Reach (RM 1.9 to 11.8)

Tributyltin ion was detected in 223 of the 433 subsurface samples analyzed within the Study Area. Concentrations reported range from 0.32J to 90,000 µg/kg, with a mean of 1,410 µg/kg (Table 5.2-2). Tributyltin ion concentrations in subsurface sediment within the Study Area are presented on Figure 5.2-41~~50~~ and Maps 5.2-34a-o.

Tributyltin ion concentrations reported at concentrations greater than 1,000 µg/kg are present in Swan Island Lagoon and extending downstream in the eastern nearshore zone through RM 7 (Figure 5.2-41~~50~~). A single result greater than 1,000 µg/kg was reported at RM 5.6. Mean concentration in these areas in are 196 µg/kg at RM 5-6, 1,250 µg/kg at RM 7-8, 13,700 µg/kg at RM 8-9, and 5,380 µg/kg in Swan Island Lagoon (Table 5.2-4).

Within the western nearshore zone there were no reported tributyltin ion concentrations greater than 1,000 µg/kg (Figure 5.2-41~~50~~). Concentration greater than 1,000 µg/kg were reported in the navigation channel near Swan Island Lagoon and downstream to RM 8 (Maps 5.2-34a-o). The highest reported concentrations the subsurface sediment are generally found at the same surface locations where tributyltin ion concentrations are greater than 1,000 µg/kg along the eastern nearshore zone (Maps 5.2-34a–o).

Within the Study Area, eight results greater than 10,000 µg/kg, 14 are between 1,000 and 10,000 µg/kg, 35 results were reported at concentrations between 100 and 1,000 µg/kg, 88 results were between 10 and 100 µg/kg, 62 were between 1 and 10 µg/kg, and 16 results were reported at concentrations less than 1 µg/kg (Table 5.2-9).

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Downstream Reach (RM 0 to 1.9)

Tributyltin ion was not analyzed in subsurface sediment samples within the Downstream reach.

5.2.12.4 Tributyltin Ion Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships were examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area. There are insufficient data to compare surface and subsurface concentrations in the Upriver and Downstream reaches. However, due to the geologic structure of the upriver reach, it is unlikely that there would be subsurface sediment contamination.

Within the downtown reach, the mean tributyltin ion concentrations are 75 and 1,052 µg/kg in surface and subsurface sediment, respectively With the Zidell data excluded, this relationship is reversed, and the mean concentrations in surface and subsurface sediment are is 55 and 4.5 µg/kg, respectively.

Within the Study Area, tributyltin ion concentrations are generally greater in the subsurface than in surface sediments, the mean concentrations are 466 and 1,410 µg/kg in surface and subsurface sediment, respectively. Most areas throughout the Study Area reach lack a strong or consistent vertical concentration gradient, although the majority of the contamination appears in the shallower near-surface samples. This pattern may be due to the lack of samples, and is supported by Maps 5.2-34d-j. This suggests a recent historical source or sources of tributyltin ion in the Study Area.

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